MAY 17 1948

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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY CHAS. COOPER AND J. FOSTER PETREE.

OFFICES FOR ADVERTISEMENTS AND PUBLICATION, 35 & 36, BEDFORD ST., STRAND, LONDON, W.C.2.

VOL. 165—No. 4292 *Registered at the General Post Office as a Newspaper* *LONDON: FRIDAY, APRIL 30, 1948.* PRICE 1s. 6d. POSTAGE { INLAND 2½d. FOREIGN 3d.

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IMPACT LOADING OF STRUCTURES.

By D. LAUGHARNE THORNTON, M.I.C.E.

THE effect of rapid loading on the mechanical properties of various materials of construction is a matter of practical interest in several branches of engineering, for experiment shows that these properties are affected somewhat by the rate of loading. In particular, both normalised mild steel and annealed cast steel exhibit an increase in the yield stress under dynamic tensile loading. Information on the results of recent impact tests with different kinds of steel in tension will be found in the two papers which were read before the Institution of Mechanical Engineers, on April 11, 1947, by F. V. Warnock and J. B. Brennan, and by A. C. F. Brown and R. Edmonds, of which certain aspects were discussed in ENGINEERING, vol. 163, page 337, (1947). In addition to guns, ships and fortifications subject to the effects of an explosion or impact, applications occur in the design of dams and other structures for seismic regions, and in the development of metals for certain forming operations. In almost all of these instances the loading is characterised by rapid rate of deformation and short duration. When the duration is very short, of the order of a millisecond, and the intensity of loading is high, as in an explosion, the part of the structure receiving the load does not change its position sensibly during the action, though appreciable changes of momenta take place; this is called impact loading. If the resulting stress in the material exceeds the yield point, yielding will take place, usually near the point of impact, but the position is influenced to some extent by the constraints, since plastic flow may be brought about some distance away from the point of impact, as in the work of riveting, where the desired degree of constraint is provided by the difference in weight of the hammer used by the riveter on the one hand, and the holder-up on the other. It is of interest to remark here that, in riveting, the duration of loading may be ten or more times longer than that associated with an explosion, thus showing that the interval of time may vary within relatively wide limits. Evidently the propagation of plastic strain is much more complicated than that of elastic strain, though the latter is the natural starting point for a general discussion on the dynamical aspect of the matter.

Consider, then, the propagation of elastic strain in a uniform circular bar of which both ends are normal to the longitudinal axis, O X, of the bar. Let the load in the form of a blow be evenly distributed over the left-hand end of the bar, and applied at time $t = 0$. With the origin $x = 0$ at the left-hand end of the bar, let the metal be specified by density ρ, Young's modulus E, and Poisson's ratio $\frac{1}{m}$. Further, since the transverse strain is of some importance here, let k represent the radius of gyration of the cross-section of the bar about the axis O X, so that $k^2 = \frac{1}{8}d^2$ for a circular cross-section of diameter d.

Fig.1.

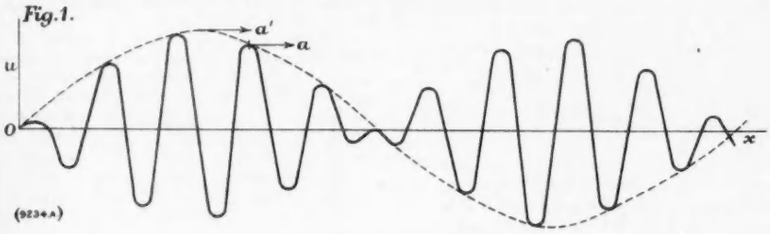


Fig.2.

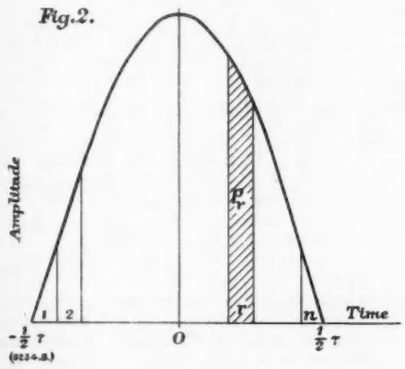


Fig.4.

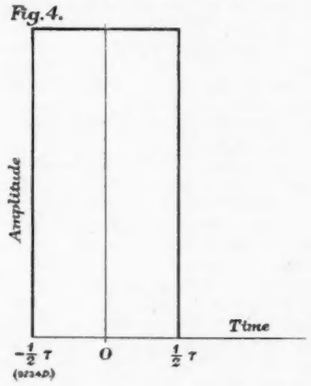
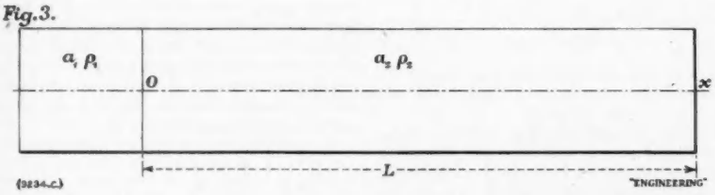


Fig.3.



Application of the load will cause the bar to execute extensional vibrations in accordance with the relation*

$$\rho\left(\frac{\partial^2 u}{\partial t^2} - \frac{k^2}{m^2}\frac{\partial^4 u}{\partial x^2\,\partial t^2}\right) = E\frac{\partial^2 u}{\partial x^2}, \quad . \quad (1)$$

where u represents the shift, or displacement, at time t of the particles lying in a plane normal to O X and distant x from the origin.

To fix ideas as to the rate of loading, suppose the resulting strain wave to be of the simple harmonic shape

$$u = A\cos 2\pi\nu\left(\frac{x}{a} - t\right), \quad . \quad . \quad (2)$$

so that ν is the frequency of vibration, and a the velocity of propagation. Making the substitution in equation (1) leads to

$$\frac{E}{\rho} = a^2 + \frac{4\pi^2\nu^2k^2}{m^2} = a^2\left(1 + \frac{4\pi^2k^2}{m^2\lambda^2}\right),$$

from the general relation $\nu\lambda = a$, where λ represents the wavelength; or

$$a = \frac{a_0}{\left(1 + \frac{4\pi^2k^2}{m^2\lambda^2}\right)^{\frac{1}{2}}}$$

where $a_0 = \sqrt{\frac{E}{\rho}}$, the velocity of propagation of an elastic wave in a wire made of the material. This means that for a given bar the velocity a is not constant; it depends on the frequency or, in more general terms, on the ratio of the diameter of the bar to the wavelength. The wave is then said to suffer dispersion as it advances.

Equation (2) relates to a special type of wave; the shape is simple harmonic and the train extends to infinity in both directions. But the expression is linear, so that to the same degree of accuracy we can, with the help of Fourier's theorem, build up by superposition a solution which will satisfy any arbitrary initial conditions. Since with an actual pulse or blow the subsequent motion is, in general, made up of systems of such waves, of all possible wavelengths, travelling in either direction, each with the velocity proper to its own wavelength, the shape of the pulse will change with the time, the harmonic components of longer wavelength travelling faster than those of shorter wavelength in the case of extensional vibration. The only exception will occur when the wavelength of every component present in appreciable amplitude is large in comparison with the diameter of the bar. In the case of two simple-harmonic wave-trains of the same amplitude, but of different frequencies and velocities of propagation, for example, the resultant displacement

$$\begin{aligned} u &= A\cos\left\{2\pi\nu_1\left(\frac{x}{a_1} - t\right) + \alpha_1\right\} \\ &\quad + A\cos\left\{2\pi\nu_2\left(\frac{x}{a_2} - t\right) + \alpha_2\right\} \\ &= 2A\cos\left\{\pi\left(\frac{\nu_1}{a_1} + \frac{\nu_2}{a_2}\right)x - \pi(\nu_1 + \nu_2)t + \frac{\alpha_1 + \alpha_2}{2}\right\} \\ &\quad \times \cos\left\{\pi\left(\frac{\nu_1}{a_1} - \frac{\nu_2}{a_2}\right)x - \pi(\nu_1 - \nu_2)t + \frac{\alpha_1 - \alpha_2}{2}\right\} \end{aligned} \quad . \quad . \quad . \quad (3)$$

The two factors on the right represent a simple-harmonic wave-train of frequency $\nu = \frac{1}{2}(\nu_1 + \nu_2)$ and velocity of propagation

$$a = \frac{a_1 a_2(\nu_1 + \nu_2)}{a_2\nu_1 + a_1\nu_2}$$

in the first place, and one of frequency $\nu' = \frac{1}{2}(\nu_1 - \nu_2)$ and velocity of propagation

$$a' = \frac{a_1 a_2(\nu_1 - \nu_2)}{a_2\nu_1 - a_1\nu_2}. \quad . \quad . \quad (4)$$

in the second. If ν_1 is nearly, but not quite, equal to ν_2, the period of the second of these waves will be very long, and equation (3) will represent a simple harmonic wave-train with a slowly varying amplitude, the maximum value occurring at a time $\frac{x}{a'}$ later than it occurs at $x = 0$. Fig 1 illustrates the kind of graph obtained by plotting the displacement u at a given instant against the distance x, the profile of the wave being drawn in full line and that of the "group" in broken line. The noteworthy characteristic is that the wave-form changes as it advances, with a period $\frac{1}{\nu'}$, but the maximum reappears at intervals; the individual waves of a group travel with the local wave-velocity, but change their periods, lengths and velocities as they travel.

When the disturbance consists of simple harmonic wave-trains with frequencies within the narrow range extending from ν to $\nu + \Delta\nu$, and the rate of change of velocity with respect to frequency is small, on putting in equation (4) $a_2 = a$, $a_1 = a + \Delta a$, $\nu_2 = \nu$, $\nu_1 = \nu + \Delta\nu$, and making $\Delta\nu$ tend to zero, the velocity of propagation of the maximum amplitude

$$a' = \frac{a}{1 - \frac{\nu}{a}\frac{da}{d\nu}} = a\left(1 + \frac{\nu}{a}\frac{da}{d\nu}\right) \quad . \quad . \quad (5)$$

* A. E. H. Love. *Mathematical Theory of Elasticity*, (fourth edition), Art. 278.

approximately, or, in terms of the wavelength λ,

$$a' = a - \lambda \frac{da}{d\lambda}$$

$$= \frac{a_0}{\left(1 + \frac{4\pi^2 k^2}{m^2 \lambda^2}\right)^{\frac{1}{2}}}$$

$$= \frac{a}{\left(1 + \frac{4\pi^2 k^2}{m^2 \lambda^2}\right)}. \quad . \quad . \quad (6)$$

The symbols a' and a, in turn, represent the velocity of transmission of the maximum amplitude and of a surface of constant phase, and are therefore known as the "group velocity" and "phase velocity," respectively; the phase velocity is commonly called the wave velocity. According to equation (6), in extensional vibration the group velocity can never exceed the phase velocity, though the magnitude of a' is practically equal to that of a or a_0 for small values of the ratio $\frac{k}{\lambda}$. With Poisson's ratio $\frac{1}{m} = \frac{1}{4}$, for instance, a exceeds a' by less than 3 per cent. when $\frac{k}{\lambda} = \frac{1}{10}$; but a is nearly $3\frac{1}{2}$ times larger than a' when $\frac{k}{\lambda}$ is equal to unity.

The important thing to notice is that the "group," as such, does not advance; it appears at a certain place, dies away, reappears reversed in a new place, again dies away, reappears in its original form at another place, and so on. The group velocity is, perhaps, even more important than the phase velocity, because in wave motion generally it represents the rate at which the energy is transmitted, in that periods, wavelengths and wave-velocities are transmitted with the group velocity.

With actual materials, in which damping attends the transmission of stress, the value of the group velocity may differ somewhat from that given by equation (6), since the effect even of slight damping of the viscous type is dispersion and distortion of the wave.* For elastic deformation, the dissipation of energy per cycle due to this cause is given by the area of the hysteresis loop of the stress-strain diagram.

In the case of flexural vibration, on the contrary, the group velocity is greater than the phase velocity, as may readily be demonstrated by means of the usual expression for the transverse vibration of a slender bar of material, namely

$$\rho \frac{\partial^2 v}{\partial t^2} = -\mathrm{E} k^2 \frac{\partial^4 v}{\partial x^4}, \quad . \quad . \quad (7)$$

where v denotes the transverse displacement, k the appropriate radius of gyration of the cross-section, with the other symbols as before. Taking

$$v = \mathrm{B} \cos 2\pi\nu \left(\frac{x}{a} - t\right)$$

as a simple-harmonic solution of equation (7), the resulting expression

$$a = \left(\frac{4\pi^2 \mathrm{E} k^2}{\rho}\right)^{\frac{1}{2}} \nu^{\frac{1}{2}}$$

shows that the wave velocity depends on the frequency of vibration. Hence, by equation (5),

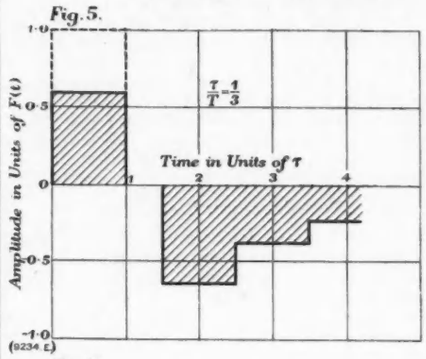
$$a' = a\left(1 + \tfrac{1}{2}\frac{\nu}{a}\frac{a}{\nu}\right) = \frac{3}{2}a.$$

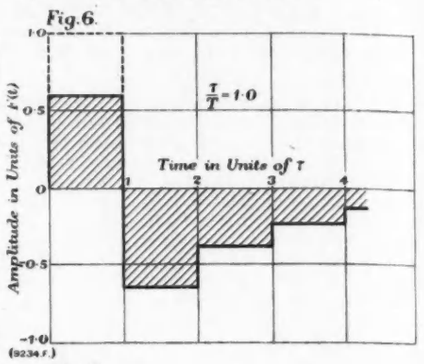
In a given bar, therefore, shorter waves will travel faster than longer ones, as occurs, for example, in the "jump" of a gun or in the "flip" of a rifle. Thus it is seen that with a combination of extensional and flexural deformations the wave front may be overtaken by components which follow it, and its steepness thereby increased as the pulse is transmitted in the material. Similarly, it may be shown that dispersion occurs also in the torsional vibration of such bars, except in the case of a circular cross-section.

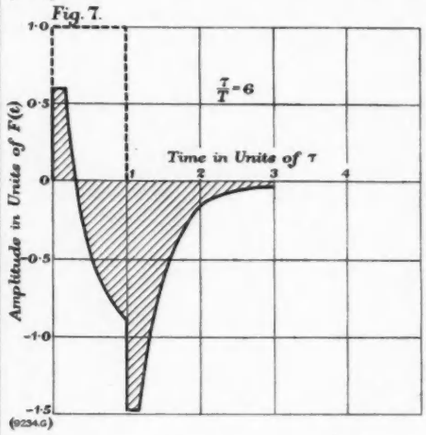
So far, our discussion has been restricted to the transmission of elastic strain, and in all such instances it is known that the strain energy can be expressed as a quadratic function of the components of strain. It is also known that, for a given material, one effect of exceeding the proportional limit is a

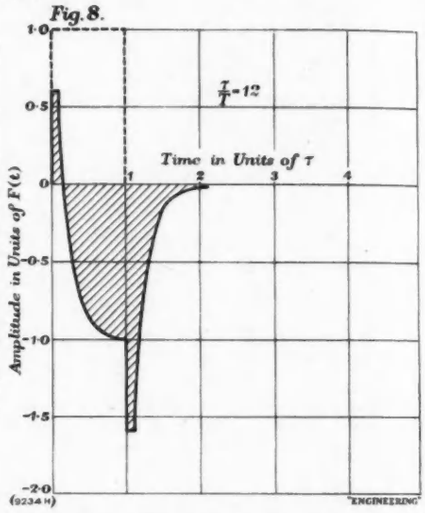
* D. Laugharne Thornton, *Mechanics Applied to Vibrations and Balancing*, Art. 71.

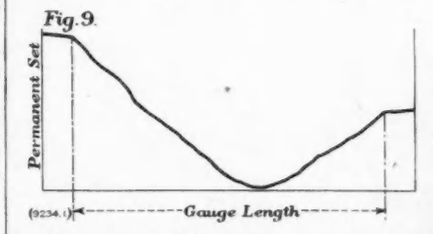
IMPACT LOADING OF STRUCTURES.











non-linear relation between stress and strain. In these circumstances the strain energy, in a first approximation, may be taken as depending on the quadratic form of both the first and the higher derivatives of the components of strain. Application of the method, which is general, to the transmission of strain in one direction only, say parallel to the x co-ordinate, will suffice for the purpose of exhibiting the propagation of strain in these conditions.

Consider an element of the material, and write u for its displacement parallel to the x-axis of reference, and ρ for the density, then the expressions for the kinetic energy, T, and the strain energy, W, per unit volume of the material, become

$$2\mathrm{T} = \int_0^{\mathrm{L}} \rho \left(\frac{\partial u}{\partial t}\right)^2 dx$$

and

$$2\mathrm{W} = \int_0^{\mathrm{L}} \left\{ c_1 \left(\frac{\partial u}{\partial x}\right)^2 + c_2 \left(\frac{\partial^2 u}{\partial x^2}\right)^2 + c_3 \left(\frac{\partial^3 u}{\partial x^3}\right)^2 + \ldots \right\} dx, \quad . \quad . \quad . \quad . \quad (8)$$

where L represents the length of the element in the x-direction, and $c_1, c_2, c_3, \ldots$ represent appropriate coefficients of stiffness. In the most general case of deformation, Young's modulus, Poisson's ratio and other moduli of the material enter into the equations of motion through the c-coefficients.

Lagrange's equations cannot be used for formulating the motion, because the element consists of a continuous system of particles, but Hamilton's principle, which includes them, can be used for the purpose. If we picture the element as passing from one configuration or state of strain to another, and compare the natural motion with any other imaginable though not necessarily natural modes of transit which differ infinitely little from each other between the same two configurations, then this principle asserts that, if the time of passing from one configuration to the other is prescribed, the time-integral of (T − W) has a stationary value in the actual path when compared with the varied paths, it being understood that all of these paths are smooth curves. Hence, with the interval (t_0, t_1) defining the prescribed time of transit,

$$\delta \int_{t_0}^{t_1} (\mathrm{T} - \mathrm{W})\, dt = 0,$$

whence, by the relations (8),

$$\delta \int_{t_0}^{t_1} dt \int_0^{\mathrm{L}} \left\{ \rho \left(\frac{\partial u}{\partial t}\right)^2 - c_1 \left(\frac{\partial u}{\partial x}\right)^2 - c_2 \left(\frac{\partial^2 u}{\partial x^2}\right)^2 - c_3 \left(\frac{\partial^3 u}{\partial x^3}\right)^2 - \ldots \right\} dx = 0$$

is the condition to be satisfied.

In performing the operation of variation, indicated by δ, on the quantities under the sign of integration, we may, in a first approximation, treat $\rho, c_1, c_2, c_3, \ldots$ as constants, and so state the above condition in the form

$$\int_{t_0}^{t_1} dt \int_0^{\mathrm{L}} \left\{ \rho \frac{\partial u}{\partial t}\frac{\partial \delta u}{\partial t} - c_1 \frac{\partial u}{\partial x}\frac{\partial \delta u}{\partial x} - c_2 \frac{\partial u'}{\partial x}\frac{\partial \delta u'}{\partial x} - \ldots \right\} dx = 0,$$

where u' is written for $\frac{\partial u}{\partial x}$. The next step is to integrate the first term partially with respect to t, and the remaining terms partially with respect to x. If, following the usual procedure with Hamilton's principle, δu is put equal to zero at both the time limits t_0 and t_1, and the coefficient of δu in the resulting expression is then put equal to zero, it appears that the equation of motion of the element is

$$\left\{ \rho \frac{\partial^2 u}{\partial t^2} - c_1 \frac{\partial^2 u}{\partial x^2} + c_2 \frac{\partial^4 u}{\partial x^4} - c_3 \frac{\partial^6 u}{\partial x^6} + \ldots \right\} = 0,$$

i.e.,

$$\rho \frac{\partial^2 u}{\partial t^2} = c_1 \frac{\partial^2 u}{\partial x^2} - c_2 \frac{\partial^4 u}{\partial x^4} + c_3 \frac{\partial^6 u}{\partial x^6} - \ldots\ldots \quad (9)$$

The physical interpretation of this result is as follows. When one end of a long bar is deformed at a rate greater than the permissible velocity of impact for elastic deformation, the stress will be propagated by the wave system $\frac{c_1}{\rho}\frac{\partial^2 u}{\partial x^2}$ together with the wave systems $\frac{c_2}{\rho}\frac{\partial^4 u}{\partial x^4}$, $\frac{c_3}{\rho}\frac{\partial^6 u}{\partial x^6}$, . . . travelling at velocities that will, in general, decrease with increasing strain. This has the effect of spreading out the distribution of strain with the time and of making the velocity of transmission of the stress a function of the strain. Here $\frac{c_1}{\rho}\frac{\partial^2 u}{\partial x^2}$ relates to an "elastic" wave, and $\frac{c_2}{\rho}\frac{\partial^4 u}{\partial x^4}$, $\frac{c_3}{\rho}\frac{\partial^6 u}{\partial x^6}$, . . . relate to "semi-elastic" waves the characteristics of which will resemble those of "plastic" waves more and more as the stress approaches the effective yield point of the material. This is, perhaps, the place where we most of all require further experimental data on the behaviour of metals under high rates of strain, since it is possible that at the frequencies occurring in impact loading, of the order of 20,000 cycles per second, the limits of elastic deformation may be sensibly higher than the values for statical loading; further, with a large deformation, the elastic moduli also may differ considerably from their normal values, and not remain constant as assumed in the above discussion of the subject. In the matter of Poisson's ratio, for example, according to recent measurements by A. H. Stang, H. Greenspan and S. B. Newman* in the case of a particular mild steel the value of $\frac{1}{m}$ increased rapidly to 0·40 when the yield point was passed, and then much more slowly to 0·43 when the extension amounted to 2 per cent., 0·27 being the mean value within the elastic range. On comparing these values with that for pure lead under small strain, viz. 0·446, it is seen that this mild steel at 2 per cent. extension differed but little in this regard from lead.

With a given material, the actual expression for the strain energy W is probably more complicated than is suggested by the relations (8), these being the simplest possible assumptions to make. Further complication may arise due to change in value of the c-coefficients with increase in strain, as just pointed out in regard to Poisson's ratio for large deformations. Be this as it may, the theory shows, and experience confirms, that a solitary pulse will develop into a wave-train the length of which increases with the distance travelled from the origin of the disturbance. In the neighbourhood of the disturbance the energy is dispersed, so that examination of what occurs there when the stress exceeds the yield point may well involve the study of elastic waves superposed on relatively uniform plastic flow. In the course of such tests, which have an obvious bearing on the initiation of the phenomenon of yield in metals, the attempt should be made to bring the work done in plastic deformation into relation with the difference between the dissipation of energy, including dispersion, in elastic and in plastic deformation; also to obtain a relation between the particle velocity $\frac{\partial u}{\partial t}$ and the stress p for strains beyond the elastic range.

Other inferences may be drawn from equation (9). One is that a train of waves may accompany the phenomenon of yield even when the load is applied gradually. Another is that, for a given metal, the experimental curves of strain-time in tension on the one hand and in compression on the other may differ in certain particulars, owing to the circumstance that initially the velocity of the particles is in the direction of propagation in the case of compression, but in the opposite direction in the case of tension. Arising from this is the question of the yield point in the plastic bending of bars, for according to E. Bernhult† many tests show a higher yield point in flexural deformation than in extensional deformation of the same metal. From the point of view presented here these two types of deformation are distinguished by a difference in the ratio of the group velocity to the phase velocity, being greater than unity in the former case, and not greater than unity in the latter. Therefore in tests arranged to ascertain whether the higher yield point is real or only apparent, as is believed by some investigators, due attention should be paid to the above-mentioned factors, including the difference between the ratios of the relevant velocities.

Before passing to other considerations, it is worth noting that the general application of Hamilton's principle to the case of a metal having a well-defined yield point requires experimental verification as to the upper limit of the admissible strain, since the effect of this characteristic may violate the condition that the actual and varied paths are smooth curves. To carry out this verification, however, we require a strain-time diagram with four variables, x, y, z and t, for at a given instant any sensible deformation of a metal usually involves all three co-ordinates of reference. This has much to do with what occurs in the case of a large structural system, and more particularly a mass structure, as, for example, heavy fortifications of reinforced-concrete subjected to bombardment by shells.

Turning now to the case of a specimen or structural member of finite length, we observe that the pulse will suffer partial reflection and partial transmission when it meets with an appreciable change in the cross-section or in the mechanical properties of the material; the reflection will be nearly complete at the end of a bar which may be regarded as an interface of the material and air. To particularise, let the solitary pulse of duration τ shown in Fig. 2, page 409, be applied uniformly over the left-hand end of the bar of unit cross-sectional area in Fig. 3, on the same page. The mechanical properties of the material on the left of the interface at $x = 0$ are taken as different from those on the right of the interface, and to indicate this difference we shall write ρ for the density, a for the velocity of propagation of the strain, and attach to these symbols the suffix 1 or 2 according as the material is on the left or the right of the interface. Thus the stress will travel with velocity a_1 in the material to the left of $x = 0$, and with velocity a_2 in the material situated between the limits $x = 0$ and $x = L$ in Fig. 3. Suppose, further, that both ends of the bar and the interface are plane and normal to the x-axis, and the end at $x = L$ is free.

Now imagine the original pulse as made up of a conveniently large number, n, of equally-spaced elements, and consider the rth element of mean amplitude p_r as indicated in Fig. 2; also, for the moment, ignore any dissipative agencies which may operate during the disturbance. If, for brevity of working, we put z_1 for $a_1\rho_1$ and z_2 for $a_2\rho_2$, then it may be shown* that the stress associated with the element p_r will undergo partial reflection and partial transmission at the interface $x = 0$, the fraction $\frac{z_2 - z_1}{z_2 + z_1} p_r$ being reflected, without change of sign or shape, with the velocity a_1 in the direction of x negative; and the fraction $\frac{2z_2}{z_2 + z_1} p_r$ transmitted, without change of sign or shape, across the interface, with the velocity a_2 in the direction of x positive. Taking this to occur at time t, and writing K for $\frac{z_2}{z_1}$, the state of affairs then may be described as a reflected stress of amplitude $\frac{K-1}{K+1} p_r$ travelling with velocity a_1 to the left, and a transmitted stress of amplitude $\frac{2K}{K+1} p_r$ travelling with velocity a_2 to the right.

The transmitted part of p_r will undergo almost complete reflection, with change of sign, at $x = L$ and time $t + \frac{L}{a_2}$, return to the interface $x = 0$ and, at time $t + \frac{2L}{a_2}$, undergo partial transmission and partial reflection there, but without change of sign or shape. In this way, for the element p_r alone, the initial reflection, $\frac{K-1}{K+1} p_r$, will be followed, after an interval or time-lag $t + \frac{2L}{a_2}$, by a stress of amplitude $-\left(\frac{2}{K+1}\frac{2K}{K+1}\right) p_r$, or, on multiplying both numerator and denominator by $(K-1)$, $-\frac{4K}{K^2-1} \times \left(\frac{K-1}{K+1}\right) p_r$. This process of reflection and transmission of stress in the material between the limits $x = 0$ and $x = L$ will subsequently take place at regular intervals of $\frac{2L}{a_2}$, so that, from the same cause, stresses of amplitude $-\frac{4K}{K^2-1}\left(\frac{K-1}{K+1}\right)^2 p_r$ and $-\frac{4K}{K^2-1}\left(\frac{K-1}{K+1}\right)^s p_r$ will be transmitted across the interface to the left at times $t + \frac{4L}{a_2}$ and $t + \frac{2sL}{a_2}$, respectively. These remarks obviously apply to each element of the incident pulse, from p_1 to p_n, and the pulse reflected at $x = 0$ to the left is the sum of the n elements reflected at, and transmitted across, the interface.

It is not a difficult matter to effect this summation, for it is usually possible to express the incident pulse, $F(t)$, which is a function of the time, by a Fourier series. Since the shape of each element is unaffected by the several reflections and transmissions, the reflected pulse, $G(t)$, also may be expressed by a Fourier series, whence the above results may be summarised in the form

$$G(t) = A_0 \int_{-\frac{1}{2}\tau}^{\frac{1}{2}\tau} F(t)\,dt + \sum_{r=1}^{\infty} A_r \int_{rT-\frac{1}{2}\tau}^{rT+\frac{1}{2}\tau} F(t)\,dt, \quad \ldots \quad (10)$$

where the travel time $T = \frac{2L}{a_2}$, $A_0 = \frac{K-1}{K+1}$, and $A_r = -\frac{4K}{K^2-1}\left(\frac{K-1}{K+1}\right)^r$, with $r = 1, 2, 3, 4$ ..... The symbol T clearly represents also the time-lag or change in phase brought about by the interface at $x = 0$. This equation shows that for certain values of the ratio $\frac{\tau}{T}$ the reflected pulse $G(t)$ may differ appreciably in shape from the incident pulse $F(t)$, owing to the "overlapping" effect of the negative terms under the sign of summation.

To exemplify this, consider the rectangular pulse indicated by Fig. 4, page 409, and let $K = 4$. Now $F(t)$ is constant between the limits $-\frac{1}{2}\tau$ and $\frac{1}{2}\tau$, so equation (10) may be arranged in the simpler form

$$G(t) = A_0 F_{-\frac{1}{2}\tau}^{\frac{1}{2}\tau} + \sum_{r=1}^{\infty} A_r F_{rT-\frac{1}{2}\tau}^{rT+\frac{1}{2}\tau}$$

where $A_0 = \frac{3}{5}$ and $A_r = -\frac{16}{15}\left(\frac{3}{5}\right)$. The changes in shape given by this expression for the reflected pulse when the values $\frac{1}{4}$, 1, 6, and 12 in turn are assigned to the ratio $\frac{\tau}{T}$ are shown in Figs. 5 to 8, opposite, where the incident pulse is indicated by broken line, and the reflected pulse by full line with hatching. Starting with a value of $\frac{\tau}{T}$ less than unity, for which the reflected pulse always consists of two distinct parts, it is seen that within a certain range of values of $\frac{\tau}{T}$ the maximum amplitude of the reflected pulse increases with increase in the value of $\frac{\tau}{T}$, being about 60 per cent. greater than that of the incident pulse when $\frac{\tau}{T} = 12$ and $K = 4$. Thus, in the prescribed conditions, the material to the left of the interface may be subjected to a stress sensibly greater than that produced there by the incident pulse, but of opposite sign. This increase is to be attributed to the sudden release of stress when a steep-fronted wave, of which this is the limiting case, is terminated, for the total incident energy is always equal to the total reflected energy when the effect of dissipative agencies is ignored.

We may follow the same procedure in the case of a damped pulse and so exhibit the effect of slight nal friction of the viscous type by curves

* *Jl. Research, National Bureau of Standards*, vol. 37, page 211 (1946).

† *Jernkontorets Annaler*, vol. 127, page 491 (1943).

* Laugharne Thornton, *ibid.*, Art. 69.

similar to those already obtained. The general effect of such damping is dispersion and distortion to an extent that depends on the variation of phase-change with frequency, as demonstrated in the previous reference to literature on the subject. On going into the matter, it will be found that the effect of these dissipative agencies increases in importance as the curve of phase-change plotted against frequency deviates more and more from a straight line.

With a specimen or structural member having both ends fixed, the pulse, in travelling to and fro, will suffer reflection at the ends, by an amount depending on the degree of fixity there. If the velocity of impact is large enough, permanent set of the material will take place at both ends, due to the direct action of the impact at one end, and to the transmitted pulse at the other. After several such impacts, we may therefore expect the permanent set gradually to diminish, reach a minimum value, and then increase as the other end is approached, as indicated in Fig. 9, page 410. The greatest amount of set will naturally occur at the end receiving the impact, and the dispersion, together with the coefficient of reflection and damping, will determine the ratio between this and the maximum set at the other end. An example of such set is shown in Fig. 4 of the above-mentioned paper by Warnock and Brennan. Reflection at the ends of the bar may, of course, cause the high-frequency oscillations at the rear of the reflected pulse to become more complicated than is suggested by Figs. 5 to 8.

The occurrence of relatively large amplitudes of stress in the reflected pulse of these diagrams raises the following question for further experimental study in the case of a steep-fronted pulse of short duration: for how long can a given material sustain a specified stress greater than the normal elastic value without undergoing permanent set? This point is of practical importance in the development of materials to withstand impact loading, and of interest experimentally because the mechanical properties of the material are not necessarily the same for the reflected pulse as for the incident pulse, owing to the initiation of permanent set in the early stages of the disturbance. Furthermore, for a particular direction, the stretching of a metal, while making for increase in strength in tension, does not improve the strength in compression in the same proportion.

We are now able to realise in a general way how the pulse is affected by the phenomenon of dispersion, including internal reflection. The front of the incident pulse may be followed by a more sustained stress or strain, probably pulsating, and even reversing in sign near points on the path which are distinguished by a sharp change in the cross-section or in the mechanical properties of the material. Thus a pulse of short duration at the outset will gradually extend as it travels away from its origin, the trend being for one group of waves to predominate in the early stages of the disturbance, and for two groups to predominate in the later stages; an approximate representation of the characteristic pattern of these later groups is given by Fig. 1. Since dispersion itself introduces a progressive reduction of amplitude as the waves travel, the appearance of the record of an impulse is a function of the distance of the recording instrument from the source of the disturbance, a point of first importance in experimental work on the subject.

With a specimen of metal having a well-defined yield point, of which mild steel is a notable example, permanent set of the material usually starts at one of the fillets, and we may then have an interface of material, partly plastic on one side and almost perfectly elastic on the other, intersecting the path of an extensional wave in the case of an impact test in tension. Subsequent applications of the load cause the interface to advance along the bar in a manner which has been investigated experimentally by Warnock and Brennan in the paper already mentioned. In this regard the foregoing discussion of an interface suggests the utilisation of a record of the reflected pulse for the purpose of exploring the permanently-deformed material, in much the same way as the seismologist draws inferences concerning the internal constitution of the earth from the study of the record of an earthquake. A specimen of rectangular cross-section is, perhaps, the best for the purposes of such exploration because a section of this shape facilitates the application of a slightly eccentric load which, in the writer's experience, makes for an interface that is sharp and nearly normal to the longitudinal axis of the specimen after a series of such loads has been applied, with the eccentricity first on one side of the minor axis of the cross-section and then on the other. If, after the final impact, the specimen is reduced to a bar of approximately uniform cross-section, by cutting off the ends, the practical scope of this method can be assessed by means of a "supersonic" flaw detector applied at the permanently-deformed end of the bar. A detector of this type to give a pulse of wavelength of about 0·2 cm. in steel is available, though the transmitter-receiver part of it may require modification for the purposes of this work. With a prescribed frequency, we may obtain a record of the incident pulse, for comparison with the reflected pulse, by adjustment of the dimension L in Fig. 3 in accordance with the foregoing analysis and, from a single specimen, records of the reflected pulse for different values of the ratio $\frac{\tau}{T}$. In favourable circumstances, comparison of the incident and reflected pulses for a given value of $\frac{\tau}{T}$ affords means of estimating K, which is made up of factors that characterise the mechanical properties of the metal on each side of the interface, viz., a_1, ρ_1, a_2 and ρ_2. The real difficulties are the practical ones of securing a uniform distribution of stress over the cross-section for the incident pulse and fairly constant values for the quantities z_1 and z_2 coupled with a sharp interface. It is desirable also to arrange the test so that the incident pulse is normal to the interface, to minimise the complications of refraction, the consideration of which we omit here in order to present the problem in its simplest form, since, as H. and B. S. Jeffreys point out,* refraction in dispersive media is rather complicated, the lines of constant phase being, in general, inclined to those of constant period. For the same reason we omit the problem of surface waves, although it is doubtful whether these waves could, in any case, be identified on records taken a short distance from the source of the disturbance.

In this field of engineering we must sometimes consider a wave or pulse having a spherical or nearly spherical front initially, as occurs, for example, when a shell hits a mass-structure of reinforced concrete. Following the instant of impact, the spherical wave travels in the material and thus produces a stress in the radial direction away from the origin of the disturbance and, simultaneously, a stress in the transverse direction which produces shear. With p and q written for the radial and the transverse stress, respectively, it may be shown† that in magnitude

$$p = \frac{m\,\mathrm{E}}{m^2 - m - 2}\left\{(m-1)\frac{\partial u}{\partial r} + 2\frac{u}{r}\right\}$$

and

$$q = \frac{m\,\mathrm{E}}{m^2 - m - 2}\left(\frac{\partial u}{\partial r} + m\frac{u}{r}\right),$$

where the radial and transverse stretch of the material in turn is denoted by $\frac{\partial u}{\partial r}$ and $\frac{u}{r}$. From the ratio of the velocity of the radial wave to that of the transverse wave, viz., $\sqrt{\frac{2(m-1)}{m-2}}$, it follows that with Poisson's ratio $\frac{1}{m} = \frac{1}{4}$, say, the extensional stress will travel in the material $\sqrt{3}$ times as fast as the shear stress. The difference between the magnitudes and the velocities of propagation of these stresses are matters for special consideration in deciding on the distribution of the reinforcements of such structures when the impact loading is more or less restricted in direction.

With particular reference to metals, a study of the subject should bring under review both the metallurgical and the dynamical aspects, relating to the behaviour of the metal in the first place, and in the second to the manner by which the load is applied, the rate of deformation and the effect on the stress of variations in the shape and dimensions of the structural member. Experimental data on these two aspects are of great practical value to the engineer, because the information enables him to formulate the permissible intensity of shock or impact or, in more general terms, a damage factor. On this point expression is sometimes given to the view that the maximum value of the resulting acceleration of the principal member of the structure is the most important factor, but this merits further consideration owing to the different interpretations which have been placed on the word intensity in this sense. Generally it has been applied to the resulting damage, and sometimes to the magnitude of the shock. Evidently it may mean, and indeed has been made by different writers to mean, the measure of the damage; the energy per unit area of wave-front of a single pulse; the rate at which energy is transmitted across unit area of a plane parallel to the wave-front; and the total energy expended in the production of the initial shock. These definitions involve quantities which may be calculated in some instances, but they are not identical, numerically or otherwise, and it is clearly inaccurate to apply the word intensity to all of them. Furthermore, the damage is sometimes assumed to be the result of oscillations following the shock; while this assumption is not always strictly true, it is probably not so far erroneous as materially to vitiate the results in certain cases.

In the writer's opinion, however, with rapid loading of a structural system of given type, the measure of the damage or intensity is best expressed by the relation (i) intensity = acceleration × amplitude × constant, or (ii) intensity = work of the impulsive force × constant, depending on the kind of data available for estimating the damage and also on the type of structure under consideration. These two formulæ are mutually consistent; (i) implies a knowledge of the amplitude, while (ii) implies a knowledge of the time involved in the action. The important thing to note in the above relations is that the "constant" term varies from type to type, a dwelling of the usual construction being one, and a multi-storeyed office building with a steel frame being another. The reaction of these two structural types to blasting operations in a nearby quarry differ in several particulars, and this difference should be indicated by the term under consideration. Again, with ships, we may for this purpose divide them into two main classes, mercantile and naval, and then sub-divide these classes so as to form structural types. Thus the sub-division of the mercantile class should distinguish between liners, freighters, tankers, and so on, and a relevant constant would apply to each of these types.

* *Mathematical Physics*, Art. 17.11.

† Laugharne Thornton, *ibid*, Art. 77.

STEEL TUBES FOR STRUCTURAL WORK.—A second edition of a booklet entitled "Steel Tubes for Structural Work: Specifications and Data," has been published by Messrs. Tubewrights Limited, Brook House, Upper Brook-street, Park-lane, London, W.1. The booklet, which was first published in 1943, contains data on the properties of steel tubes up to 12¾ in. outside diameter. The properties given include such data as weight in lb. per foot, area of cross-section in sq. in., internal volume in cub. ft. per foot, and also moment of inertia and modulus of section.

THE ROLLS-ROYCE CIVIL MERLIN ENGINE.—Messrs. Rolls-Royce Limited, Derby, have issued an interesting brochure which sets out the service obtained by air-line operators from civil Merlin engines in 1947, during which they accumulated a total of 18½ million aircraft miles. Two different series of civil Merlin were in use, namely, the two-speed, single-stage, supercharged 500 series, and the two-speed, two-stage supercharged 620 series, the former being fitted to the Avro "York" and "Lancastrian," and the latter to the Canadair "North Star" and the Avro "Tudor IV." The Merlin 500 series engines operated throughout the year at an established overhaul life of 840 hours, but some operators ran a number for an overhaul life of 1,000 hours, and, as a result of these trials, it is anticipated that a 1,000-hour overhaul life will be established in 1948. The Merlin 600 series of engines have commenced with an overhaul life of 600 hours, but it is anticipated that within a relatively short time this also will be extended to 1,000 hours. The brochure also points out that during 1947 Messrs. Rolls-Royce formed a subsidiary company in Canada, including a technical branch which gives advice on the installation, maintenance and repair of Rolls-Royce engines,

LITERATURE.

Statistical Methods in Research and Production, with Special Reference to the Chemical Industry. Edited by DR. OWEN L. DAVIES. Published for Imperial Chemical Industries, Limited, by Oliver and Boyd, 98, Great Russell-street, London, W.C.1, and Tweeddale-court, Edinburgh. [Price 28*s.* net.]

LORD MCGOWAN, in his foreword to this volume, introduces it as "the first of a series of scientific and technical handbooks which Imperial Chemical Industries intend to publish with the aim of making generally available the important body of information accumulated as the result of the company's manufacturing experience and research." Its authorship is shared by seven members of the staff of Imperial Chemical Industries, who have collaborated in describing the statistical methods found useful in connection with the activities of the organisation. These methods are naturally exemplified by data drawn from the chemical manufacturing industry, but this detracts in no way from the general usefulness of the volume; methods of statistical reasoning are the same whatever the subject-matter to which they are applied, their object being to derive the most trustworthy conclusions from any kind of data affected with the inevitable discordancies of practical measurements. The appearance of the manual is evidence of the recognition by a great industrial firm of the powerful tool that statistical science has placed at the disposal of manufacturers, not only for "quality control" of repetition products but as an aid to simple judgment in almost every department of a works.

The present book is not intended as an introduction to the theory of statistics, and parts of it may be found difficult reading by anyone not already possessing a fair knowledge of the subject. It is likely to be best appreciated as a work of reference for those engaged with statistical investigations of various kinds. As by far the greater part of industrial data may be assumed to obey the Normal Law of Error, the consequences of this Law are given most attention, though the binomial, Poisson, and other distributions are also considered. In everyday work, such questions as the confidence that can be placed in the reality of apparent improvements or otherwise, consequent upon altered conditions of manufacture; the correlation that exists between the various properties of a substance, or between any other presumably related facts; and the probable accuracy of the final result of numerous steps in an investigation, each of which contributes its own share of uncertainty to the result, provide perhaps the most important opportunities for statistical reasoning. All such matters are very well dealt with, and the principles of sampling and the use of quality-control charts are also explained. The authors consider the "probable error" as a measure of exactness to be especially avoided, and it may be agreed that the "standard deviation" to which it is directly proportional is more convenient mathematically; but the former term, which signifies that deviation from a stated average value about which an even bet could be made that such a deviation would not be exceeded, conveys to the ordinary man a good idea of the size of error to be expected. The notion of a standard deviation is bound up with that of a frequency distribution, and to obtain a graphical representation of an empirical distribution the authors recommend dividing the data into groups of equal range and plotting the stepped figure known as a "histogram." They deprecate the practice of afterwards smoothing out the irregular steps into a continuous curve as liable to be misleading. This may be so when the smoothing is done by eye, but if, as an alternative to the histogram—which, even at its best, has a kindergarten sort of appearance—a cumulative curve, or "ogive," is constructed from the data, and the differential of the ogive is then plotted, the result is a frequency curve to which no reasonable objection can be taken. This procedure, recommended by Dr. Ulick Evans some years ago, might well have been mentioned, as it involves very little trouble.

In innumerable cases, the relationship between two varying quantities can be expressed with quite sufficient accuracy by a simple linear equation, which may be regarded as the first approximation to any form of curve. The straight-line law, which is the graphical embodiment of this fact, is familiar to engineers in connection with the steam consumption of a turbine, or the heat consumption of an entire power station, as the load on either is increased. The best location of such "regression lines" among scattered experimental points, and the degree of confidence that may be placed in deductions from them, can both be determined statistically. Also, when the appearance of the points indicates that a straight line would not represent them with sufficient accuracy, an equation of the second or higher order can, of course, be used; its parameters being determined, as in the simpler case, by the method of least squares. In dealing with these matters it should have been pointed out that in many instances the use of an equation comprising any term with a quadratic or other even power is inadmissible. If, for example, an even term were included in an equation connecting the total cost of running a factory with the total output over equal periods, it would imply that the cost was affected by some influence that would make it just as expensive for a factory to accept goods as a present, as it would be to prodnce the same quantity with its own material and labour. Such a state of affairs is obviously absurd, however satisfactory the equation might be to the mathematician.

The book appears to cover about every application of statistical processes that is likely to be of use in a manufacturing industry. The tables required for calculations of probability and significance are naturally included, and the full glossary of statistical terms is likely to be appreciated by readers not entirely conversant with the special vocabulary of the science. Messrs. Imperial Chemical Industries are to be congratulated on their enterprise in sponsoring this addition to statistical literature, which might well be given a place in every industrial library, and future publications under the same patronage will be awaited with interest.

Ventilation and Air Conditioning. By E. L. JOSELIN, A.M.I.C.E., M.I.H.V.E. Edward Arnold and Company, 41 and 43, Maddox-street, London, W.1. [Price 21*s.* net, including folding plates also obtainable separately: "Friction of Air in Ducts," 9*d.* net; "Air Conditioning Chart," 1*s.* net.]

THIS is the second edition of a well-known text-book, originally published in 1934. The author was for many years lecturer at the Borough Polytechnic, London, one of the few educational institutions in this country to provide a course in heating and ventilation, and recently recognised as the National College in these subjects.

There is no lack of books on heating, and many of them deal also with ventilation, though usually in a cursory manner. Any authoritative work which takes ventilation as its main theme is therefore welcome to students and to engineers. As would be expected, the author is well acquainted with the numerous papers bearing on the subject, published in the proceedings of professional institutions and elsewhere, and frequently refers to them in the text: it would have been an advantage if the actual sources had been quoted in all cases. The book, however, is by no means purely academic, and most of the illustrations and examples are of a severely practical kind. It begins with chapters on the properties of atmospheric air and standards of ventilation. Among other instruments, the eupathoscope is described, but the statement that it is only calibrated for use in still air is incorrect: its fundamental purpose is to integrate the effect on comfort of various factors, including air movement. A fuller discussion of various comfort scales would have been of interest, together with an explanation of methods of measurement of air changes within a room. Several charts are given for use in the design of ventilation and air-conditioning systems. These include a new duct-friction chart (which might preferably have been in nomographic form) based on the I.H.V.E. standard formulæ. The design of ventilation systems and their components is admirably treated.

Air conditioning is dealt with in outline only, and much more might have been said about this increasingly important branch of engineering. A psychrometric chart is given: it was prepared by the author from I.H.V.E. and other standard data, but is necessarily similar to the chart reviewed on page 520 of our 156th volume (1943). A Bulkeley chart is given also (Fig. 217), but this is on much too small a scale to be useful. Incidentally, Fig. 218, showing the method of using the new chart, should have been included on it, particularly on the copies which are sold separately. In any subsequent edition of this book, a much fuller account of air conditioning would be desirable. Other additions which might usefully be made are numerical exercises following appropriate chapters, a separate index of tables, and a selected bibliography of relevant British and American literature. As it stands, however, the book will continue to serve the needs of students, and will be a most useful acquisition to any engineer concerned with ventilation and allied problems.

Appareillage et Usinage des Matières Plastiques. Volume I. By J. LESCUYER. Collection Matériaux de Synthèse. Dunod, 92, Rue Bonaparte, Paris, (VIe.) [Price, 1,380 francs.]

THE collection "Matériaux de Synthèse," published under the direction of Professor Piganiol, is now firmly established and its popularity is attested by the fact that second editions of three of the volumes already issued are in preparation. The latest addition to the series forms the first part of a work by Mr. Lescuyer dealing with the equipment developed for the preparation of plastic materials and the manufacture of plastic products. The first chapter summarises the requisite conditions for the shaping and machining of the various plastics. It includes a comprehensive tabulation of the mechanical and physical properties of synthetic rubbers and the chief thermoplastic and thermosetting substances. Even approximate preforming minimises the subsequent operations of drilling, turning and polishing and economises material, though often such material as is removed during the finishing processes can be ground down and used again.

The moulding of plastics involves pressures of 1 to 3 tons per square inch in compression moulding, and up to 20 tons per square inch in injection moulding, temperatures up to 200 deg. C., and times from a few seconds to several minutes. Installations for carrying out such sequences of operations on a manufacturing scale are analysed in Chapter II, typical modern units being described and illustrated. A useful section on recording instruments, permitting the regulation of pressure and temperature within appropriate limits, is included. Chapter III is devoted to machines for preparing and handling plastics in the form of syrup, dough or powder and for incorporating fillers and colouring matter, due consideration being given to safety devices. A wide range of machinery designed to carry out miscellaneous industrial processes on plastics is described in the concluding chapter. Among these processes are those producing laminated plastics, plastic-coated articles, films, sheets, rods, tubes and threads.

No attempt has been made to catalogue all existing types of machines. Mr. Lescuyer has wisely selected from his extensive experience examples representative of recent practice, has studied their components and special features in adequate detail, and has provided references to the literature wherever possible. The large number of illustrations—348—is a valuable feature. Most of them are clear, though a few would be easier to follow had they been reproduced on a larger scale. The information presented in this book was not readily obtained, for it is still no easy matter to persuade competing firms to furnish technical details of the equipment they manufacture. Closer co-operation in this respect would be to the advantage of all concerned in the plastics industry. Future improvements in the quality of plastic articles presuppose an intimate knowledge of the existing machines used in their manufacture, for it is only on this basis that still more efficient machinery can be devised. Mr. Lescuyer's book, with its authoritative analysis of present-day practice, makes an important contribution to this end.

SPEED AT SEA AND DISPATCH IN PORT.*

By W. MacGillivray.

Table I, herewith, which was extracted from the annual report of Lloyd's Register of Shipping for the year 1937-38, illustrates the relative proportion of reciprocating steam engines, steam turbines, and internal-combustion engines fitted in vessels built to class since 1918. It is also an index to motive power and shows for the same period the proportion of tonnage propelled by the use of coal and by the use of oil, either as fuel for boilers or motors.

No comparable statistics were published during the war, and the report bringing the figures up to date will not be available until March, 1948; it is thus difficult to obtain accurate information as to the types of machinery favoured by shipowners in ships constructed since the war. The figures in Table II have been compiled from the *Shipping World* and relate to ocean-going vessels constructed, or under construction, or on order during the period April 1, 1946, to September 30, 1947. The information covers only ships, both British and foreign, built in British shipyards; it does not include short-sea traders, coasters, etc. The information for the respective periods is not, strictly speaking, entirely comparable, and this must be borne in mind when analysing the figures. Nevertheless, the figures are sufficiently reliable to indicate the trend of post-war shipbuilding design.

Taking an overall picture and comparing it with 1937-38, the percentage of motorships is approximately the same, but steam turbines have materially increased, while steam reciprocating vessels have rather substantially decreased, as shown in Table III. At first glance, it would appear that shipowners who favoured steam reciprocating machinery immediately prior to the war, are now turning over to turbines; but this is not so. Tramp shipowners are, in fact, having steam reciprocating machinery in 58 per cent. of the gross tonnage under construction or ordered by them in the 1946-47 period. The cause of the comparatively large increase in ships with turbine machinery has to be sought in the passenger and cargo-liner class. One reason, doubtless, is that the faster ships lost during the war are being replaced by turbine-engined vessels. There is, however, in the tonnage at present under construction and on order, a tendency for some liner owners to install turbines in ships of even moderate power where of recent years Diesels were preferred. This applies not only to British, but also to some Continental shipowners, although not to Scandinavians, who are, in proportion to their total tonnage, the largest users of motorships. Liner owners, doubtless, have good reasons for preferring the particular type of prime movers they use, but opinions vary as to the growing trend towards steam turbines in certain types of ship. One of them is the shorter time and lower costs involved in maintenance and repairs, a very material factor in these days. It is not only the actual repairs which are so expensive to-day, but also the time involved. Damage which may cost only a few hundred pounds to repair may mean the loss of several times that amount in delay to the ship.

In deciding upon the type of machinery, a shipowner naturally takes into consideration the probable cost of the appropriate grade of fuel. Table IV, opposite, shows the costs of oil at some of the principal bunkering ports over the past few years. At the present moment, world demand for oil is in excess of its production and this is likely to continue until the new oilfields in the Middle East are brought into operation. There is a shortage of refining plant, pipe lines, and tankers. Domestic requirements in the United States are so great that that country has now to import oil. It is inevitable that prices, both for boiler and Diesel oil, will increase.

It is a little too early to say whether the experiments being carried out by the Anglo-Saxon Petroleum Company in their motor tanker Auricula will meet with such success that other shipowners generally will follow their example and equip their Diesel ships to operate on boiler oil. From the information already available, it seems evident that, in the past twelve months, during which the vessel completed a dozen voyages, covering about 70,000 miles, the results have been encouraging. So long as the present differences in the respective prices exists, there is a substantial saving in fuelling costs if a motor ship can use heavy oil, as supplied to oil-fired ships

Two developments occurred during the recent war, which in course of time will present shipowners with new means of propulsion, and with them new problems. Gas turbines have been the subject of experiments for a number of years. For a 10,000-ton cargo ship of 15 knots, fitted with a 6,800 shaft horse-power closed-cycle gas turbine, a fuel consumption (heavy fuel oil) of 0·49 lb. per shaft horse-power per hour is claimed for the propulsion unit, compared with 0·6 lb. for a steam turbine. This economy would amount to a saving in the fuel bill of about 6,000*l.* a year. It is anticipated that, when developments in metallurgy enable temperatures to be increased, the fuel consumption will be reduced to 0·38 lb. per hour, approximately the same as a Diesel engine. The first cost of a gas turbine is expected to be only four-fifths that of a steam turbine. In a recent broadcast it was declared that, within five years, it should be possible to design power stations operated by atomic energy, to be used in conjunction with either steam or gas turbines, and that atomic plants would be installed in large ships. The possibilities of atomic energy certainly open up a wide field of speculation for shipowners.

In the search for economy and efficiency, a good deal of attention is being paid to auxiliary machinery and winches. The electrically-operated type are becoming very popular, although opinions are divided as to whether they are really more economical over a period, especially after, say, about ten years. Noiseless enclosed steam winches with splash lubrication are now available which are almost as silent as electric winches and just as fast. Steam winches probably stand up better to careless handling by stevedores. The additional cost of electric auxiliaries and generators is now about 25,000*l.* for a 10,000-ton deadweight 15-knot cargo liner. The following is a comparison of two sister motorships built in 1944, one with steam and the other with electric auxiliaries. Over a period of 1,300 days (500 at sea and 800 in port) the fuelling costs were 5,710*l.* with electric auxiliaries and 14,201*l.* with steam auxiliaries. The ship with electric auxiliaries carries two electricians; the number of engineers and engine-room staff is otherwise the same.

It is difficult to make an accurate comparison of the cost of repairs to the respective sets of auxiliaries as a good deal of maintenance work was done by the ships' engineers. It is necessary to take into consideration depreciation at 6 per cent. per annum and interest at 4 per cent. on the additional capital outlay of 25,000*l.* for the electric auxiliaries. The complete comparison is, therefore, 21,473*l.* for electric auxiliaries and 16,531*l.* for steam.

There has been a definite tendency in recent years to increase the speed of both cargo liners and tramps. The former are now generally 13 to 15 knots for small ships and 15 knots and upwards for larger vessels; tramps have stepped up from 10 knots to about 12 knots. All this can be achieved only at considerable cost. Building prices are now about two and a half to three times above 1939 figures, according to the size and type of ship, and the peak is not yet in sight. Part of the increase is due to many shipowners now requiring a superior specification with refinements in crew accommodation, ventilation, lifeboats, fire-detection apparatus, etc. The price curve rises steeply as the speed of a 10,000 ton deadweight cargo liner increases above 12 knots. To raise the speed of a Diesel-driven vessel of this size to 15 knots means an addition to the building price of about 130,000*l.* to 150,000*l.* This in itself means 13,000*l.* to 15,000*l.* per annum for depreciation and interest. The additional expense does not stop there. The faster ship becomes a more refined ship all round; the fuel consumption increases about two and a half times and the cost of operating rises considerably. Does the building of faster ships bring to the shipowner a commensurate reward? Despite the greatly increased capital outlay and heavy operating costs, the time occupied by a 15-knot ship crossing the Atlantic is only two days less than that of a 12-knot vessel. From London to Buenos Aires the saving in time is 4½ days. There is no corresponding gain in port, as the slower vessel can load and discharge just as quickly.

It was usual in pre-war days to count upon a ship as being roughly 200 days at sea and 165 days in port. The following statistics are taken from the records of a cargo-liner company which might be regarded as typical. Its ships vary in size from 3,000 tons to 11,000 tons deadweight, and the speed from 12 knots to 15 knots. The types of propulsion are Diesel, steam turbines, and steam reciprocating, coal or oil. During the war, over a period of six years, the average earnings of this fleet were almost exactly what the Ministry of Transport intended them to be, namely, a basic rate of hire per gross registered ton to cover operating costs, plus 10 per cent. per annum on the first cost of the ships for depreciation and interest. The fleet can be regarded as a fair sample of the cargo-liner industry. In 1937 and 1938, the average number of days per vessel spent at sea and in port were 204 and 161, respectively. During 1946 and 1947, the corresponding figures were 163 days at sea and 202 in port, a reversal of the pre-war time. The averages vary somewhat in individual trades. In one trade where a fairly accurate comparison can be made, as the small type of ships employed are always nearly full of cargo, the times

TABLE I.

Year.	Total Steam and Motor Tonnage Classes (including Auxiliaries).	Type of Engines.						Fuel.			
		Steam Reciprocating.		Steam Turbines (including Turbo-Electric).		Inter-combustion Engines (including Diesel-Electric).		Coal.		Oil.	
	Thousand Tons Gross.	Thousand Tons Gross.	Per cent.	Thousand Tons Gross.	Per cent.	Thousand Tons Gross.	Per cent.	Thousand Tons Gross.	Per cent.	Thousand Tons Gross.	Per cent.
1918-19 ..	3,760	2,633	70	1,051	28	76	2	2,491	66	1,269	34
1925-26 ..	1,324	576	44	146	11	602	45	418	32	906	68
1932-33 ..	447	119	27	140	31	188	42	110	25	336	75
1937-38 ..	1,503	433	29	192	13	878	58	291	20	1,211	80

TABLE II.

——	Turbines.		Turbo-electric.		Diesel.		Steam Reciprocating.		Steam Reciprocating. Reheat.		Steam Reciprocating. Exhaust Turbines.		Total.	
	No.	Tons Gross.	No.	Tons Gross.	No.	Tons Gross.	No.	Tons Gross.	No.	Tons Gross.	No.	Tons Gross.	No.	Tons Gross.
Liners:														
18 knots and over	14	252,000	3	19,000	2	25,000	—	—	—	—	—	—	19	296,000
16 and under 18 knots	38	390,000	—	—	34	351,000	—	—	—	—	—	—	72	741,000
14 and under 16 knots	41	308,000	—	—	65	430,000	2	16,000	—	—	5	32,000	113	786,000
Under 14 knots ..	7	41,000	—	—	42	213,000	4	15,000	—	—	23	83,000	76	352,000
Speed not stated	21	168,000	1	8,000	28	149,000	2	10,000	—	—	1	7,000	53	342,000
	121	1,159,000	4	27,000	171	1,168,000	8	41,000	—	—	29	122,000	333	2,517,000
Tramps	3	18,000	—	—	32	164,000	37	171,000	12	59,000	4	21,000	88	433,000
Tankers	1	8,000	4	44,000	79	712,000	9	46,000	1	6,000	—	—	94	816,000
	125	1,185,000	8	71,000	282	2,044,000	54	258,000	13	65,000	33	143,000	515	3,766,000

TABLE III.

——	Steam Turbines, Per cent.	Internal-combustion, Per cent.	Steam Reciprocating, Per cent.	Total, Per cent.
1937-38 ..	13	58	29	100
1946-47 ..	33	54	13	100

* Paper presented at the Spring Meeting of the Institution of Naval Architects, held in London, March 17-19, 1948. Abridged.

were, in 1938-39, 197 days at sea and 168 in port; and, in 1946-47, 146 days at sea and 219 in port. These ships are therefore spending 51 days a year more in port than they did prior to the war, which, in this particular trade, represents one round voyage lost.

Conditions ashore to-day, particularly in some countries, can only be described as deplorable. The time which shipowners are saving at sea through building faster ships at very great cost is being entirely nullified by detention in port, for which post-war conditions are mainly responsible. It is difficult to measure in terms of money these delays and their effect on transport costs, but it is apparent that they are very considerable. There is thus little saving, if any, in operating costs, and delays in home ports are equally as expensive as delays abroad.

The shipowners' greatest individual worry to-day is dispatch in port. Labour is the key to the situation and until the growing tendency to do less and less for more and more ceases, there will not be any improvement. Starting work late, finishing early, restrictive practices—all these combine to reduce output. These troubles will not disappear overnight and it will take time for the upheaval caused by the war to subside. Good wages and an improved standard of living are essential and desirable things, but, in the long run, they must be combined with a good day's work. A return to the 1939 level, however, should only be a stage in the ultimate aim to reduce the time spent in port. This aspect of shipowning has not, in the past, received the attention it deserves. The speed at which a ship can discharge or load her cargo depends chiefly upon the efficiency of port equipment and organisation, brought alongside or taken from the vessel. Where acceleration is necessary in many cases is on shore.

Derricks should be long enough to reach outboard to plumb barges that may have to berth alongside at an angle, if the whole of the cargo is being discharged overside, so as to keep all holds working together, or to plumb at least two lines of rails when working ashore. One heavy derrick at the main hold for cargo liners is almost essential nowadays, with a capacity of 30 to 50 tons. Two 10-ton derricks, one forward and one aft for medium lifts, are also desirable. Large barrels on the winches are an important factor, with large smooth whipping drums. In some ports, these whipping drums are used to advantage where quantities of light general cargo have to be dealt with, particularly where the lift is restricted by labour customs.

Although British shipowners do not generally favour cranes in place of the usual winches and derricks it is noteworthy that the Swedish Johnson Line are building five 19½-knot 9,100-ton deadweight motor ships equipped with 14 electric cranes at seven holds. They have an exceptional reach of 41 ft., making it possible to handle goods even on the second railway track from the quayside. The lifting capacity of the cranes varies from 2 to 5 tons, and up to 10 tons in some hatches by operating cranes in pairs.

The "main hold" idea, one of the surviving traditions of the sailing-ship age, is still responsible for a certain amount of delay. Some 2,800 Liberty ships and quite a number of British ships were built during the war with No. 2 hold approximately twice the size of each of the others. If the cargo were homogeneous and could be loaded and discharged at a uniform rate

TABLE IV.

	1939.			1945.			1947 (September).		
	Boiler Oil.	Diesel Oil.	Extra Cost of Diesel Oil.	Boiler Oil.	Diesel Oil.	Extra Cost of Diesel Oil.	Boiler Oil.	Diesel Oil.	Extra Cost of Diesel Oil.
Bunkering Ports at Oil-Producing Centres:	s. d.	s. d.	Per cent.	s. d.	s. d.	Per cent.	s. d.	s. d.	Per cent.
Trinidad	23 0	43 0	87	33 9	55 9	67	57 6	90 9	58
San Pedro	24 6	43 0	78	36 3	52 3	44	54 3	93 9	72½
Haifa	—	—	—	31 0	50 0	61	70 0	90 0	28½
Balik Papan ..	40 0	50 6	25	—	—	—	—	—	—
Average ..	29 0	45 6	57	33 8	52 8	56	60 7	91 6	52
Bunkering Ports at Non-Oil Producing Centres:									
New York	25 9	48 10	90	56 9	100 0	76	74 3	100 0	35
Buenos Aires ..	45 0	85 0	89	88 3	112 6	27	107 0	139 0	30
United Kingdom ..	37 6	50 0	33	124 0	144 0	16	84 6	106 0	26
Aden	36 6	48 6	33	76 6	95 6	25	82 0	103 6	26
Singapore	44 0	54 6	24	—	—	—	98 6	120 0	22½
Fremantle	60 0	66 6	10	102 6	117 6	15	109 0	131 0	20
Average ..	41 6	59 0	43	90 0	114 0	25	92 6	116 6	26
Average, all ports	37 4	54 5	46	68 8	90 9	32	82 0	108 2	32

ship's winches and derricks, division of cargo holds, and other aids to assist dispatch.

No matter how efficient may be dock cranes, ship's derricks and winches, delays to the vessel will occur if there is congestion ashore due to slowness in removing the cargo from quays and sheds. The problem does not end here. Narrow and awkward approaches to and exits from docks and riverside wharves often produce a "bottle-neck" which results in delay throughout the various handling stages. The ideal berth for the average 10,000-ton deadweight vessel should have four 3-ton electric 70-ft. jib cranes and two 6-ton cranes, all movable under their own power, with 6-ton cranes spaced one forward and one aft, also a 15-ton crane between every two berths, all able to discharge into or load from either transit shed, lorry or railway wagon. Given such equipment, supplemented by the ship's derricks for working overside, an adequate supply of satisfactory labour, and provided the cargo can be brought alongside or removed to keep pace with the loading and discharging operations, there should be a great improvement in the present rate of dispatch. An alternative layout for a port where lighters are largely used could be a pontoon equipped with mobile cranes and separated from the quay to enable lighters to be operated between ship and quay.

Too little time is worked in port during 24 hours. Under present conditions, where there is such a shortage of labour at many ports, it seems useless to think of more than one shift of eight hours. Nevertheless, in the hope that the supply of labour will ultimately become more abundant, two shifts of eight hours each are suggested as an object to be kept in view. It is a much better system that one shift of eight hours plus overtime, which is not only costly but in some respects uneconomic.

As cargo-handling appliances are not available at all ports, especially those abroad, ships must be equipped with their own. Even without the assistance of port cranes, adequate ships' winches and derricks can handle cargo under present conditions as fast as it can be at all hatches, the ideal arrangement for dispatch would be to have holds of identical size. In open roadsteads, however, cargo is more difficult to handle when it has to be stored in the fore and aft holds; and some types of goods require a large hold. These conditions can be overcome, to a great extent, by double-rigging the large holds, and this has been recognised good practice in large cargo liners for many years.

The practice of covering hatchways in many ships differs but little from that in use on the earliest steamers and consists of heavy steel beams which support the wooden covers. As the size of hatches increased, the number of beams also increased until by now they number from 85 to 100 in a three-decked cargo vessel of average size. At least 10 per cent. of stevedores' time is occupied in the wholly unproductive work of uncovering and covering hatches at the commencement and completion of each day's work, further loss being involved in covering up on account of rain, shifting work from one deck to another, etc. The use of roller hatch beams reduces such losses to a minimum, while preserving the elasticity and convenience which the use of portable covers confers. An appreciable saving of time in port, with consequent saving of wages, is thus possible The width of the hatchway is automatically increased by seven or eight inches because the destructive beam sockets are dispensed with and damage to bag and other cargo is, for the same reason, avoided. Clear decks are ensured, as they are not encumbered with unshipped beams.

Palletisation, employed with much success by Canada Steamship Lines, in their Great Lakes' ships, is the stowage of goods on pallets or trays, and is used with the aid of fork-lift trucks and trailer-tractors for stacking and transporting. Goods can be palletised either at point of origin or on arrival at the wharf, the work in the latter case being done by the stevedore. On arrival at the wharf, the loaded pallets, weighing from one to three tons, are lifted from the vehicle by a fork-lift truck and stacked in the transit shed. Many experiments have been carried out to determine the quickest method of conveying the loaded pallets from shed to the ship's hold, and the following method has been found to be the best. A fork-lift truck unstacks the loaded pallet in the shed, places it on a trailer drawn by a tractor to the ship's side, then up a gangway through a side port to the 'tween deck and into an elevator, which conveys trailer and tractor down to the hold. The loaded pallet is lifted from the tractor in the hold by a fork-lift truck and stowed. When the elevator descends to the hold it finds an empty trailer and tractor waiting to ascend on the way back to the shed for another load. As the elevator reaches the 'tween deck and the tractor and trailer run off, another on the way from the shed with a load is waiting to descend. The time for a complete round trip of the elevator, 'tween deck to hold and return, is about 30 seconds.

The saving of labour by the system is considerable. In the loading of a typical commodity, say, cartons of canned food, 70 of which are placed on a pallet, two mechanical hauls (from shipper's lorry to transit shed and thence to ship's hold) and three mechanical handlings now do the work that formerly required 17½ hauls and 210 handlings when it was done manually. Two thousand tons of package cargo can be loaded in from eight to 12 hours at a cost which compares favourably with pre-war, although wages of longshoremen have doubled since then. While the system seems well suited to Great Lakes' traffic, it is doubtful whether full palletisation is possible in deep-sea trades. In the Great Lakes' trade, pallets can be pooled and used again on the return voyages, but not many deep-sea trades could be organised on such lines. In such trades, the greatest benefit of the system would probably be obtained by confining their employment to quay and shed operations. Palletisation of goods is certainly a system which might well be investigated in this country.

The intelligent use of mechanical trucks, portable cranes, etc., can do much to speed up cargo-handling operations, but it is necessary to guard against the danger of over-mechanisation. Unless the gear can be continuously employed, it may well result in costs being increased rather than decreased. Co-operation of labour is essential to ensure that gangs are reduced in proportion to the amount of manual work saved. There is also a tendency for labour to become so accustomed to having mechanical assistance that they cease to perform work which is cheaper to do manually.

Not everyone, even in America, is convinced that benefits automatically follow by the use of mechanical gear. The following are extracts from a speech made by Captain Blanchard at the annual meeting of the American Association of Port Authorities in October, 1944. "Let us look back 50 years and see how we have improved. The piers were then uncovered and most of the cotton was hoisted into one hatch in a sailing ship by one horse-power—just a plain everyday horse. Then came the steamer and we had to cover the piers. Cargo had to be assembled ahead of time and instead of one gang and the horse we had steam winches and many gangs. Cargo had to be thrown out with speed and piled on the pier. Then, of course, we had the longshoreman—with a strong back and a feeble mind—and the hand truck. They worked ten hours a day and more. The production at that time was about one ton per man per hour. The hand truck was a happy tool for many years and the units which were being put in the ship ran about 1,500 lb., but we had to extend that. Labour was increased and the units were raised to two tons. That was partly due to the increased capacity of the ship's gear. Then we brought in the travelling crane; the first one was a Ford tractor with a lot of mechanism, a horrible looking thing, but it seemed to do the work. Since then we have brought in the lift-truck. At first labour was a little antagonistic and, when the foreman wasn't looking, they sometimes drove it overboard. Now they almost refuse to work unless we have the equipment. But in spite of this the number of men in the gangs has had to be increased and the production per man per hour hasn't varied in the last 40 years. It is still about one ton per man per hour. That is a rather strange thing when you stop to think that we have put on the pier many thousands of dollars' worth of these patent toys. One gang years ago was about 11 men and the equipment cost about 100 dollars—a few trucks, and so on. For a gang of 22 men to-day, the cost of the equipment is about 5,000 dollars. With all these 'isms' and improvements we haven't increased the production we had in the olden days."

L.M.R. DIESEL-ELECTRIC LOCOMOTIVE.—Since April 6, the 1,600-h.p. Diesel-electric locomotive No. 10000, of the London Midland Region, has been covering approximately 3,100 miles per week of six days between Derby and St. Pancras. It is scheduled to depart at the head of express passenger trains from Derby at 8.55 a.m. and 7.37 p.m., and from St. Pancras at 2.15 p.m. and 11.50 p.m. each weekday.

DIESEL-ELECTRIC SHUNTING LOCOMOTIVE.

The Diesel-electric locomotive illustrated in Figs. 1 and 2, on this page, and in Figs. 3 to 6, on page 420, is the first of this type to be put into service on Irish railways. Altogether, five of these locomotives are being built at Inchicore Works, Dublin, and, on completion, they will be employed on shunting, and transfer work. The locomotives have been designed by Messrs. Associated Locomotive Equipment, Limited, 32, Duke-street, St. James's, London, S.W.1, for Coras Iompair Eireann, in co-operation with the latter's engineers at Inchicore. The first locomotive, number 1000, will operate over a six-mile route between Kingsbridge, Dublin and the North-Wall yards, where the greater part of Eire's rail-sea traffic is handled. This route includes a 1 in 84 gradient over a distance of 1½ miles and the locomotive is required to haul loads of 400 tons at speeds up to 25 miles an hour.

As will be seen from Figs. 1 and 2, it is a six-coupled locomotive having a wheelbase of 11 ft. 9 in. Its overall length, breadth and height are 29 ft. 2 in., 9 ft., and 13 ft., respectively. The generating set comprises a six-cylinder, pressure-charged four-stroke Diesel engine manufactured by Messrs. Mirrlees, Bickerton and Day, Limited, Hazel Grove, Stockport, directly coupled to a 290-kW direct-current generator manufactured by the Brush Electrical Engineering Company, Limited, Loughborough. The generating set is illustrated in Figs. 5 and 6, on page 420, from which it will be seen that, in addition to the main generator, there is an auxiliary generator fitted to the top of the main generator and driven from it by endless ropes. The auxiliary generator has an output of 10 kW and, in addition to other duties, is used to charge the batteries for starting the locomotive. The power from the main generator is supplied to two nose-suspended traction motors which drive the leading and trailing axles of the locomotive, the position of the traction motors being indicated in Fig. 1.

The Diesel unit is a Mirrlees type TLDT6 engine, having a bore and stroke of 8¼ in. and 13¾ in. respectively and developing 487 brake horse-power at 710 r.p.m. continuous rating, and 535 brake horse-power at the one-hour rating. It is of simple and straightforward design, special attention having been paid to accessibility and ease of stripping down for overhaul. The crankcase is in two parts, the upper half forming the cylinder column. This is a monobloc casting and has bolted to it the six individual cast-iron cylinders, each of which is fitted with a renewable wet-type cast-iron liner. The cylinder heads also are separate castings, and have been designed for use with an exhaust-gas driven turbo charger, each being fitted with two inlet and two exhaust valves; these are operated in the usual manner by push rods and rocking levers. The crankshaft is of heat-treated steel and is carried in eight main bearings of the steel-backed white-metal lined pattern. The connecting rods are machined from heat-treated H-section steel forgings; they are of the palm-ended type and are secured to the big ends by four high-tensile bolts. Aluminium-alloy pistons are used, each of which is fitted with three compression rings and two oil-control rings. The pistons are provided with hollow fully-floating gudgeon pins which work in bronze bushes; like the main bearings, the big ends are of the steel-backed white-metal lined type. The camshaft is driven through gears from the flywheel end of the engine, and in addition to operating the exhaust and inlet valves, actuates the Bryce fuel-injection pumps, there being a separate pumping element for each cylinder. The cams, however, are not integral with the camshaft but are secured to it by wedge cotters. The main bearings, big-end bearings, camshaft bearing and the timing gear are pressure lubricated, the lubricant being supplied by a gear-type pump; an electrically-driven priming pump is fitted, however, so that all bearings may be flooded with oil before the engine is started.

As mentioned previously, the engine is pressure charged by an exhaust-gas turbo charger. This is of Brown-Boveri manufacture and, as will be seen from Fig. 5, it is fitted to the flywheel end of the engine. Lubricant for the bearings of this unit is contained in two internal oil sumps, thus making it independent of the main lubricating system. The cooling water circulating pump is fitted to one side of the engine at the opposite end to the generator and is driven by endless belts from a pulley fitted to the end of the crankshaft; this arrangement can be seen in Fig. 6. The impeller is designed so that, although an adequate rate of circulation is maintained at the engine idling speed, excessive pressure is not built up at higher speeds. Cooling is assisted by a radiator and engine-driven fan, the fan being belt driven from the same pulley as the water-circulating pump. The radiator is used also for cooling the lubricating oil, there being eight elements for water cooling and four for oil cooling. It is provided with shutters for regulating the air flow, and in order to

DIESEL-ELECTRIC SHUNTING LOCOMOTIVE.

Fig. 1.

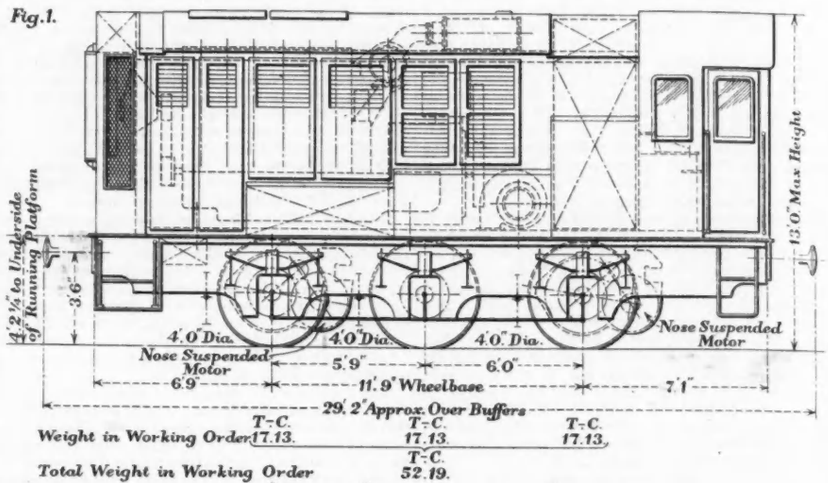
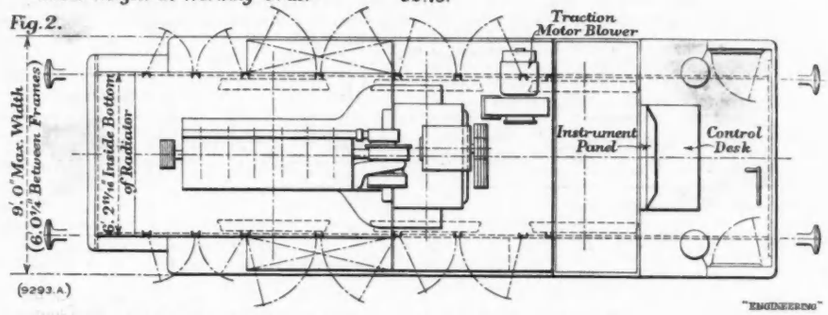


Fig. 2.



"ENGINEERING"

prevent cooling air from entering the engine compartment, the air is discharged through apertures on the side of the radiator.

To give adequate protection against the shocks encountered in shunting and transfer operations, the engine and generator are insulated from the main frame of the locomotive. This is accomplished by fitting the engine and generator to a common cast-iron bedplate which, in turn, is held to cross stays of the locomotive frame through three flexible mountings, one of which is bolted to a machined facing under the forward end of the engine and one under each side of the extended portion of the bedplate which carries the main generator. Each mounting consists of two parts, namely, a cast-steel trunnion, in which is fitted a rubber-insert bush, and a cast-steel forked bracket, the two parts being held together by a steel bolt which passes through the rubber bush and the two forks of the bracket. The rubber bush, which was manufactured by Messrs. Silentbloc, Limited, Nottinghill Gate, London, W.11, consists of a pre-loaded rubber insert located between two concentric steel sleeves.

The generator is a six-pole interpolar machine having three field windings on the main poles, so as to provide the drooping characteristics desirable for Diesel-traction work. The armature is coupled directly to a light flywheel fitted to the end of the engine crankshaft, the only bearing being a double-row self-aligning roller bearing at the commutator end of the machine. In common with usual practice, additional turns are included in the series winding so that it may be used as a series motor to bring the engine up to firing speed. The current for this purpose is provided by a 108-ampere-hour capacity 80-volt lead-acid battery stored in steel containers on each side of the locomotive. As mentioned previously, the battery is charged by the auxiliary generator fitted to the top of the main generator. The auxiliary generator is a four-pole interpolar shunt-wound machine having an output of 10 kW at 90 volts. The voltage is controlled by a carbon-pile regulator in the shunt-field circuit, so that it remains approximately constant at all engine speeds.

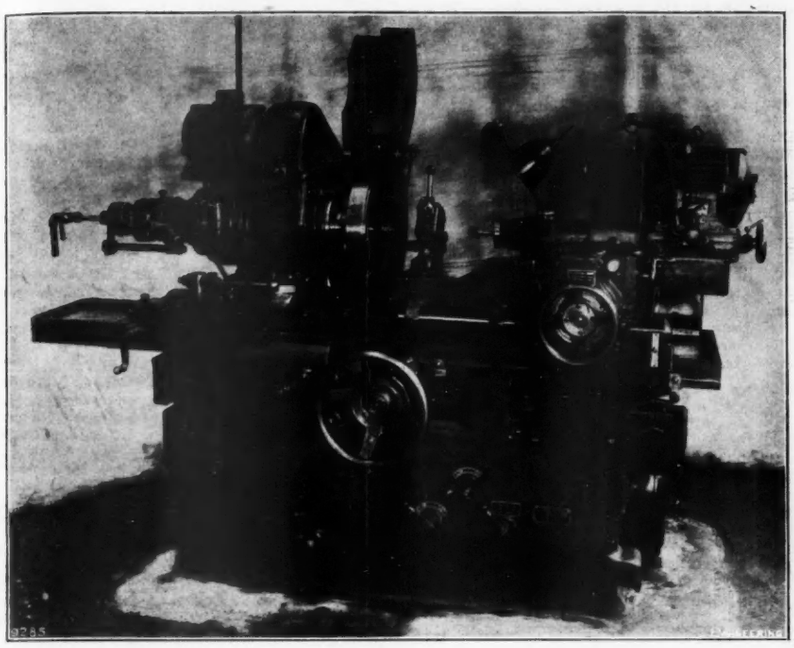
The two nose-suspended series-wound traction motors, each of 177 brake horse-power, drive the leading and trailing axles through double-reduction spur gears, the intermediate wheels being driven by side coupling rods. The reduction gears have an overall ratio of 12·24 to 1, and are arranged so that they can be disengaged when it is required to haul the locomotive at speeds in excess of 25 miles an hour. The traction motors are force-ventilated, the electrically-driven blower for this purpose being situated in the generator compartment; the blower, however, supplies the traction motors only, the main and auxiliary generators being self-ventilated. The air, both for the engine intake and the ventilation of the generators and motors, is cleaned by Visco filters fitted to the doors of the generator compartment.

The locomotive frame and superstructure are of fabricated construction. The engine and generator compartments are separated by a bulkhead which prevents the ingress of oil vapour into the electrical compartment; the bulkhead can be seen in Fig. 4, on page 420, which shows the locomotive being erected. The axleboxes are fitted with SKF self-aligning roller bearings, the weight of the locomotive being transferred to the axleboxes through semi-elliptical springs in the usual manner; as will be seen from Fig. 1, the springs are disposed outside the frame. Westinghouse compressed-air brakes are fitted, the air being supplied by an electrically-driven two-cylinder compressor fitted underneath the forward end of the locomotive. The fuel supply of approximately 1,100 gallons is carried in a tank situated between the generator compartment and the driving cab. The tank is divided into two parts, a smaller service tank being formed in the top of the main tank, and connected thereto by an overflow pipe. The fuel is supplied to the service tank by a small electrically-driven transfer pump which delivers approximately 26 gallons an hour.

The speed of the locomotive is regulated through the engine governor; this is of the centrifugal type and is driven from the camshaft through bevel gears. Speed changes are obtained by varying the load on the main spring of the governor through an oil-actuated piston, the oil being supplied under pressure by the engine-lubricating pump. The load on the piston is regulated by three adjustable pilot valves, which are set to give engine speeds of 440, 580 and 710 r.p.m. under load, respectively, the governor being set for an idling speed under load of 300 r.p.m. The pilot valves are operated by solenoids, which, in turn, are selected by a drum-and-finger type controller situated in the driving cab. For normal shunting duties the traction motors are connected in series across the main generator, but in order to fulfil the requirements for transfer operations, the motors are connected in parallel, the change from series to parallel being effected by a switch in the driving cab. Once the traction motors are connected in parallel, however, it is impossible to return to the series connections until the controller is moved to the "off" position. The series and parallel contactors, the starting contactor, and the main motor reverser are

AUTOMATIC INTERNAL-GRINDING MACHINE.

MESSRS. CHURCHILL MACHINE TOOL COMPANY, LIMITED, MANCHESTER.



electro-pneumatically operated, the air being obtained from the air-brake system; electromagnetic contactors, however, are used for auxiliary circuits, such as the air compressor. A "deadman's" pedal is fitted to each side of the cab in positions convenient to the driver irrespective of the direction of running. The release of this pedal, for a period exceeding five seconds, causes the electrical controls to be open-circuited followed by the application of the air brakes. All the control equipment has been supplied by Messrs. Allen West and Company, Limited, Brighton.

The locomotive is simple to operate, the application of power to the traction motors, the variation in the output of the main generator and the changes in engine speed being effected by the main controller. Should the locomotive be required for hump shunting, regulation of output between the main controller notches is provided by a five-notch vernier controller. The controls are duplicated so that the locomotive can be driven from either side, a combined ammeter and speedometer being mounted centrally on a swivelling bracket, so that it can be turned to face either driving position. Other instruments provided include an auxiliary-generator ammeter and voltmeter, air-brake gauge, cooling-water thermometer, and lubricating-oil temperature and pressure gauges.

The locomotive weighs 52 tons 19 cwt., in full working order. It develops a starting tractive effort of 24,000 lb., and at the lower speeds is capable of hauling a gross load of 600 tons. Running tests have shown that on greasy rails it can start from rest with a 400-ton load on a gradient of 1 in 84. This is probably the first occasion on which a Diesel engine developing over 500 brake horse-power has been used as the prime mover for a three-axle Diesel-electric locomotive. It will be appreciated, however, that this high output is not required for shunting or hump operations, but is needed to move trucks along the main line without occupying the sections for too long a period.

THE INSTITUTION OF ELECTRICAL ENGINEERS.—The annual general meeting of the Institution of Electrical Engineers will be held at 5.30 p.m. on Thursday, May 13, at the Institution Building, Savoy-place, Victoria-embankment, London, W.C.2. Copies of the accounts for the year ended December 31, 1947, and the annual report of the Council, which will be considered at the meeting, can be obtained from the secretary. The formal business will be followed, at about 6.45 p.m., by the exhibition of a film dealing with the history and development of atomic energy. Admission to this will be by ticket, which can be obtained by members on application to the secretary. Tickets for visitors will not be issued until after Tuesday, May 4, by which date it is hoped the requirements of members will have been ascertained.

AUTOMATIC INTERNAL-GRINDING MACHINE.

THE automatic-sizing internal grinding machine illustrated on this page has been designed by the Churchill Machine Tool Company, Limited, Broadheath, Manchester, for the grinding of long bores which require separate roughing and finishing operations. The work is carried by a traversing table which reciprocates along the length of the machine during the grinding operations, the cross feed to the grinding wheel being operated automatically at each reciprocation of the work table. The maximum length of bore that can be ground and the maximum swing inside the guard is 12 in., but by removing the guard the swing can be increased to 18¼ in.; in the illustration, part of the guard is shown in the open position.

The work table is traversed hydraulically, the complete process of grinding being divided into a roughing operation and a finishing operation. The hydraulic power traverse is engaged by the withdrawal of a ball-handled lever projecting from the front cover of the machine, followed by the movement of the hand reverse lever. This causes the work table to move to the right, as viewed in the illustration, at a speed of 35 ft. per minute. After the table has moved a predetermined distance, a dog fitted to the table depresses the truing-speed throttle valve. It is only necessary, however, to true the grinding wheel during the run up for the finish-grind operation, so an interlock is fitted which prevents the table from slowing down to the truing speed during the rough-grind operation, the table continuing to advance 35 ft. per minute until a second dog on the table makes contact with the traversing-valve control lever. This lever is connected to, and operates, a butterfly valve located at the outlet from the main valve, the subsequent throttling action causing the speed of the table to be reduced for the grinding operation.

The grinding wheel, which can be seen to the right in the illustration, is driven by a separate motor through a flat belt. The grinding head is located in a slide arranged at right angles to the slide for the work table so that the wheel can be fed into the work by moving the grinding head along its slide. In order to relieve the grinding-head slide from the weight of the drive, however, the motor is fitted to a separate slide which is connected to the grinding head through a link so that it can follow the movement of the grinding wheel. The feed of the grinding wheel is regulated by a cam which is rotated by a simple piston and link mechanism. This is arranged so that at the instant the work table is slowed down for the grinding operation, the piston is connected into the hydraulic system, the pressure of the oil on the piston causing the cam to rotate and the cross feed to commence. The work table reciprocates along the length of the machine during the grinding operation, the oscillations being controlled by rollers which are depressed by dogs fitted to the work table, the rollers, in turn, operating the necessary valves in the main hydraulic system through a system of levers. As previously mentioned, the complete grinding process is divided into two operations, namely, rough grind and finish grind. When the roughing-peak of the cam is reached, a depression on the cam allows the grinding head to withdraw from the work; simultaneously, the table reverse roller and lever is withdrawn from the path of the reversing dog and the table returns to the dead-stop position, thus completing the rough-grinding operation.

The hand reverse lever is again moved to the left and the table commences to move in for the finish-grind operation, but this time, the interlock in the truing-speed mechanism is rendered inoperative. Therefore, when the truing-speed lever is depressed, the table is slowed down and the diamond truing device swings down and trues the wheel, automatic compensating feed having been applied mechanically before the truing position is reached. When the truing-speed lever is passed, the diamond moves away and the work table accelerates to its original speed of 35 ft. per minute until the grinding position is reached, at which point it slows down and commences to reciprocate for the finish-grind operation. At the same time, the automatic cam feed commences and continues until the sizing peak of the cam is reached. This is followed by a brief dwell to give a good finish, after which the grinding head drops back and the table returns to the dead-stop position. In this position, the rotation of the work ceases, the water supply is cut off, and the component is ready to be removed from the chuck or fixture.

The truing and grinding speeds can be varied by the adjustment of small control valves operated by ball-handled levers on the front cover of the machine; these adjustments are independent of each other and do not affect the maximum speed of table traverse. The work head is arranged so that it can be swivelled on its table up to a maximum of 30 deg. towards the operator, thus permitting taper bores to be ground. The work head spindle is fitted with dual ball thrust and journal bearings and is driven through a V-belt from a separate motor, stepped pulleys giving a choice of four different work speeds. The machine illustrated is fitted with a draw-back chuck mechanism and a Churchill plate-collet chuck, but provision has been made for the fitting of other types of chucks and fixtures.

MOTOR VEHICLES IN THE ARCTIC.

THE use of motor vehicles on "Exercise Musk-Ox," the Canadian military expedition in Arctic and sub-Arctic regions in 1946, is reviewed by Major A. G. Sangster in the March issue of *The Engineering Journal*, published by the Engineering Institute of Canada. The expedition demonstrated that it is possible "to travel by tracked vehicle under conditions of wide variations of temperature, and over terrain consisting of barrier ice, wind-packed snow, boulder-strewn ground, mountains, sea-ice and 'muskeg'" (grassy bog). The vehicles used were 5-ton "snowmobiles," known as "Penguins," with Cadillac V-8 engines, automatic gear-change hydraulic transmissions, and wide tracks; each would hold five persons in a closed cab. The lowest temperature encountered was —50 deg. F., and at no time during the first two months did the temperature rise above freezing point. The wind velocity was seldom below 10 miles an hour, and the worst conditions encountered were a temperature of — 40 deg. F. and a 40-m.p.h. wind. The party did not usually travel when visibility was restricted by wind-blown snow. Throughout the exercise, there occurred no mechanical failure, preventing movement and common to all vehicles, which was directly attributable to the weather. During halts, petrol was added to the engine oil to prevent it becoming very stiff. After running the engine under load for a short time, the petrol would boil or burn away.

A 60 : 40 mixture of glycol and water was used in the radiators, and no trouble was experienced in this connection. Starting the engines presented no difficulty, provided the batteries were properly maintained and kept active by running the engine a charging speed every 12 hours. Owing to the nature of the terrain, it was generally necessary to run vehicles in the lower gears with the engines at, or near, the governed speed. The automatic transmission had not been designed for this type of service, and in the last thousand miles of the journey some failures occurred. Pneumatic tyres lost their resilience in the extreme cold, and, when frozen, were strong enough to carry the loads without air. Fuel stoppages due to dirt and sludge in the filters, and water in the petrol, caused the most trouble. Maintenance and repairs were carried out in the open, an improvised shelter being used only occasionally. Replacement engines and axles were delivered by air to the party, together with a Duralumin lifting frame.

CONTRACTS.

Messrs. G. and J. Weir, Limited, Cathcart, Glasgow, S.4, have received an order from the Netherlands Government for plants, to distil fresh water from sea water, to be erected at Curaçao and Aruba, Dutch West Indies, where large oil refineries are situated. The boilers for the plants will be made by Messrs. Babcock and Wilcox, Limited, Renfrew, and the structural-engineering work by Messrs. A. and J. Main and Company, Limited, Possilpark, Glasgow, N.

Messrs. Whatlings Limited, 10, Woodside-crescent, Glasgow, C.3, are to carry out a pipelaying contract in connection with the east main and Milngavie outlet works of the Water Department, Glasgow Corporation. The contract will involve much tunnelling work. The main connection to the 36-in. diameter east main will be made from the existing straining well at Craigmaddie Reservoir, through a control valve situated in a new valve shaft 32 ft. deep and 12 ft. in internal diameter. The contract also includes an alternative supply to the east main to be provided by an additional connection from Craigmaddie Reservoir to the new valve shaft.

Messrs. Dorman, Long and Company, Limited, Middlesbrough, have secured the contract for the construction of a road bridge over the River Tagus at Vila Franca, 20 miles above Lisbon. The bridge will require about 3,000 tons of steelwork, all of which will be rolled and fabricated in the United Kingdom. The design selected by the Portuguese Government Road Board consists of five steel arch spans, each of 340 ft., for the main river crossing, flanked on both sides by reinforced-concrete viaduct approaches. Associated with Messrs. Dorman Long in the building of the bridge is the Portuguese company, Messrs. Seth, who will be responsible for the construction of the substructure and the viaduct approaches.

LAUNCHES AND TRIAL TRIPS.

S.S. "Redon."—Single-screw cargo vessel, built by Messrs. John Readhead and Sons, Limited, West Docks, South Shields, to the order of the French Government. Main dimensions: 437 ft. 9 in. by 55 ft. 6 in. by 34 ft. to upper deck; deadweight capacity, about 7,500 tons on a draught of 23 ft. One set of Parsons geared turbines, to develop a service power of about 3,000 shaft horse-power, constructed by The Parsons Marine Steam Turbine Company, Limited, Turbinia Works, Wallsend-on-Tyne, and giving a service speed of 13 knots. Trial trip, April 13.

M.S. "Caledonian Coast."—Twin-screw vessel, with accommodation for ten passengers, built by Messrs. Hall, Russell and Company, Limited, York-place, Aberdeen, to the order of The Aberdeen Steam Navigation Company, Limited, 87, Waterloo-quay, Aberdeen, for their Aberdeen-London service. Main dimensions: 265 ft. by 40 ft. by 23 ft. 6 in. to shelter deck. Two eight-cylinder Diesel engines of about 2,560 aggregate brake horse-power, constructed by Messrs. British Polar Engines, Limited, Helen-street, Govan, Glasgow, and installed by Messrs. Hall, Russell. Trial trip, April 17.

S.S. "Løvland."—Single-screw cargo vessel, built and engined by Messrs. Smith's Dock Company, Limited, South Bank, Middlesbrough, Yorkshire, to the order of Messrs. Skipsaksjeselskapet Sunde (Samuelsens Rederi), Farsund, Norway. Main dimensions: 300 ft. by 46 ft. 7 in. by 28 ft. 3 in. to shelter deck; deadweight capacity, 3,650 tons on a draught of 18 ft. 11½ in. Triple-expansion engines, with two oil-burning boilers, developing 1,700 indicated horse-power and a speed of about 12½ knots. Trial trip, April 19.

S.S. "Avenir."—Single-screw cargo vessel, built and engined by Messrs. Smith's Dock Company, Limited, South Bank, Middlesbrough, Yorkshire, to the order of the A/S Acadia (Mr. Sigurd Bruusgaard), Drammen, Norway. Main dimensions: 300 ft. by 46 ft. 7 in. by 28 ft. 3 in. to shelter deck; deadweight capacity, about 3,600 tons on a draught of 19 ft. Fredrikstad-type steam motor developing 1,700 indicated horse-power, with two oil-burning boilers, producing a speed of about 12 knots. Launch, April 22.

M.S. "Somali."—Twin-screw vessel for the carriage of refrigerated and other cargoes, together with 12 passengers, built and engined by Messrs. Barclay, Curle and Company, Limited, Clydeholm Shipyard, Glasgow, W.4, for the Peninsular and Oriental Steam Navigation Company, 122, Leadenhall-street, London, E.C.3. Main dimensions: 525 ft. by 67 ft. by 43 ft. to shelter deck; gross tonnage, 10,700. Two sets of Barclay, Curle-Doxford six-cylinder opposed-piston oil engines, producing together 13,600 brake horse-power and giving a speed of 18 knots in service. Launch, April 22.

New Turntable at Crewe.—A new 70-ft. turntable has recently been installed at Crewe South motive power depot, London Midland Region, in place of a 60-ft. turntable. This enables the largest class of 4-6-2 express passenger engines to be turned without occupying the running lines on an adjacent triangle.

BRITISH STANDARD SPECIFICATIONS.

The following publications of engineering interest have been issued by the British Standards Institution. Copies are obtainable from the Publications Department of the Institution, 28, Victoria-street, London, S.W.1, at the price quoted at the end of each paragraph.

Clinker Aggregate for Concrete.—A revised British Standard Specification published recently is one covering clinker aggregate for plain and precast concrete. The specification, B.S. No. 1165, was first issued in 1944, and it has now been revised to include an additional class of aggregate suitable for use in plain precast concrete units where these are to be used for interior work, not exposed to damp conditions. The additional class of aggregate, to be known as Class C, has a higher permissible loss on ignition than the classes included in the previous edition, which classes were suitable for use in plain concrete for general purposes and for interior work. The inclusion of this additional class has necessitated the addition of the word "precast" in the title. Minor amendments have also been made to clarify the text and to include a modification of the soundness test to suit the new Class C clinker. [Price 2*s.*, postage included.]

Aluminium Rain-Water Goods.—A new specification, B.S. No. 1430, covering cast and extruded aluminium gutters, pipes, fittings and accessories, has been prepared and issued at the request of the aluminium industry, in order that the general features of this variety of rain-water goods should be compatible with those manufactured from other materials for which British Standard Specifications exist and also in order to secure the use of suitable alloys. The publication deals with the quality of the materials employed, dimensions, and other matters, and line drawings of all the articles dealt with are included. [Price 2*s.* 6*d.*, postage included.]

BOOKS RECEIVED.

British Transport Directory of Officials. "The Railway Gazette" Offices, 33, Tothill-street, Westminster, London, S.W.1. [Price 1*s.*]

The British Electrical and Allied Manufacturers' Association. Thirty-Seventh Annual Report of the Council, 1947-48. Offices of the Association, 36-38, Kingsway, London, W.C.2.

Ministry of Transport. Railways Division. Railway Accidents. Report on the Collision Which Occurred on the 6th November, 1947, at Molspur Park Junction on the Southern Railway. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 1*s.* net.]

The British Aircraft Industry, 1948. *A Directory of Members and Associate Members of The Society of British Aircraft Constructors Limited.* Offices of the Society, 32, Saville-row, London, W.1. [Copies available to approved applicants connected with the Industry.]

Practical Photomicrography. By R. F. E. Miller. Percival Marshall and Company, Limited, 23, Great Queen-street, Kingsway, London, W.C.2. [Price 5*s.* net.]

Ignition Equipment. By Edgar T. Westbury. Percival Marshall and Company, Limited, 23, Great Queen-street, Kingsway, London, W.C.2. [Price 8*s.* 6*d.* net.]

Practical Armature Winding. By Alfred H. Avery. Percival Marshall and Company, Limited, 23, Great Queen-street, Kingsway, London, W.C.2. [Price 3*s.* 6*d.* net.]

Politics and Poverty. By Lewis C. Ord. The Mayflower Publishing Company, Limited, 17, Farringdon-street, London, E.C.4. [Price 8*s.* 6*d.* net.]

A Pocket-Book for Mechanical Engineers. By Professor D. A. Low. 1948 edition. Edited by Bevis Brunel Low. Longmans, Green and Company, Limited, 6 and 7, Clifford-street, London, W.1. [Price 15*s.* net.]

N.C.C., 1848 to 1948. Centenary of the Opening of the Belfast and Ballymena Railway. The Railway Executive, Northern Counties Committee, York Road Station, Belfast. [Free to approved applicants.]

Elements of Strength of Materials. By Professors S. Timoshenko and Gleason H. MacCullough. Second edition. D. Van Nostrand Company, Incorporated, 250, Fourth-avenue, New York 3, U.S.A. [Price 4 dols.] Macmillan and Company, Limited, St. Martin's-street, London, W.C.2. [Price 21*s.* net.]

Applied Atomic Power. By Professor Edward S. C. Smith, Professor A. H. Fox, R. Tom Sawyer and H. R. Austin. Prentice-Hall, Incorporated, 70, Fifth-avenue, New York, U.S.A. [Price 4 dols.] Blackie and Son, Limited, 66, Chandos-place, Strand, London, W.C.2. [Price 20*s.* net.]

Construction in Reinforced Concrete. An Elementary Book for Designers and Students. By G. P. Manning. Second edition. Sir Isaac Pitman and Sons, Limited, Parker-street, Kingsway, London, W.C.2. [Price 15*s.* net.]

PERSONAL.

Mr. J. J. Sheehan, B.Sc., A.R.C.Sc.I., A.R.I.C., of the Coneygre Foundry, Tipton, Staffordshire, has been nominated by the Council of the Institute of British Foundrymen to be junior vice-president of the Institute for the year 1948-49.

Mr. E. Bolton King, who, latterly, has been on the Directorate of Guided Weapons, Ministry of Supply, has been appointed Director of the Science Department of the British Council.

Mr. F. C. Vokes, B.Sc. (Eng.) (Lond.), M.I.C.E., has been nominated chairman of the Birmingham and District Association of the Institution of Civil Engineers for the session 1948-49. Mr. K. C. Marrian, M.I.C.E., has been nominated chairman of the North-Western Association of the Institution.

Lieut.-Colonel J. Marshall, O.B.E., has been elected chairman of the North-Western section of the Institute of Transport.

Mr. J. B. Greaves, O.B.E., who was appointed to succeed Sir Robert Dalton, C.M.G., on the latter's retirement from the position of United Kingdom Senior Trade Commissioner in Australia (mentioned on page 34, *ante*) took up the post at Canberra on April 6.

Mr. P. A. H. Elliot is to-day relinquishing the position of Director of the Combustion Appliance Makers' Association (Solid Fuel), 24, Tottenham Court-road, London, W.1, which he has held for the past three years, having transferred from the British Coal Utilisation Research Association. Mr. Elliot also held the position of secretary to the Coal Industry Fuel Efficiency Committee, set up jointly by the Ministry of Fuel and Power and the Mining Association. The activities of the Combustion Appliance Makers' Association will be carried on for the time being by the assistant director, Mr. C. E. Knight.

Mr. Basil Sanderson has been elected to the Board of the Ford Motor Company, Limited, Dagenham, Essex.

Mr. S. A. Sadler Forster has been appointed full-time chairman of the North-Eastern Trading Estates, Limited, by the President of the Board of Trade.

Group Captain P. McDiarmid, O.B.E., A.F.M., who has just retired from the Royal Air Force, has joined the Plessey Company Limited, Ilford, Essex, as technical representative in the Government contracts division.

Mr. L. B. Bull, hitherto works director of Dartmouth Auto Castings Limited, Dartmouth-road, Smethwick, 40, Staffordshire, has been appointed managing director.

Major C. R. Dibben, O.B.E., who has been Midland regional secretary of the Federation of British Industries, 21, Tothill-street, London, S.W.1, since 1919, is retiring to devote more time to other industrial interests. Mr. Ion Earle, who joined the Federation in 1938 as assistant to Major Dibben, is to succeed him on September 1.

Mr. W. S. Spicer, chief buyer and stores superintendent, Hadfields Limited, East Hecla Works, Sheffield, has retired after 47 years with the company. He was elected a local director in 1946.

Mr. H. A. L. Trew has been appointed acting Press Officer of the Railway Executive (Western Region), Paddington Station, London, W.2.

The constituent members of the International Shipping Conference, 3-6, Bury-court, St. Mary Axe, London, E.C.3, have agreed to change the name of the organisation to the International Chamber of Shipping.

Messrs. Mullard Wireless Service Company, Limited, Century House, Shaftesbury-avenue, London, W.C.2, have changed their name to Mullard Electronic Products, Limited, as their activities now extend into many branches of electronics, particularly those with applications in industry, science and communications.

Messrs. Eltee Equipments, Limited, London-road, Staines, Middlesex, have been appointed sole distributors in the British Isles for Le Tourneau earth-moving equipment.

Messrs. Musgrave and Company, Limited, St. Ann's Works, Belfast, have opened branch offices at 89A, Clayton-street, Newcastle-upon-Tyne. Mr. W. J. Adams, B.Sc., has been appointed manager.

British Timken Limited, have received approval from the Ministry of Supply and a building licence from the Ministry of Works, which will enable them to proceed with their scheme for further extensions to their factory at Duston, Northampton.

The Diesel Engine Users' Association.—The annual luncheon of the Diesel Engine Users' Association was held in the Connaught Rooms, London, on April 15, under the chairmanship of the President, Mr. William Howes, M.I.Mech.E. The principal guest was Sir Harry Ricardo, F.R.S., who, in proposing the toast of "The Association," to which the President responded, remarked on the valuable work that it had done, especially in collecting records of Diesel-engine performance and running costs, during the 36 years of its existence.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Scottish Steel.—Production at local steelworks is still seriously handicapped by the shortage of scrap. Good weather and longer hours of daylight have been favouring the collection of domestic scrap, but deliveries from all sources remain on a day-to-day basis. Recent prospects that the furnaces off in Lanarkshire might soon be in operation have receded, as reasonable guarantees of adequate scrap supplies have not been forthcoming. The drive for the maximum collection of scrap from industrial areas and outlying districts is being actively pursued. Allocations in respect of most of the Scottish tonnages for Period 2 have now been made, and Scandinavian and certain Colonial markets have been favoured by quotas which are relatively fairly generous. Increasing activity is noticeable in the tubemaking trade as a result of the greater demand from British oil companies for plant and equipment of British make. Substantial tonnages of all varieties of tubes are being shipped regularly to Middle Eastern and other oilfields.

Scottish Coal.—The N.C.B. are perturbed at the lack of improvement in Scottish production. For three successive weeks this month outputs fell below 470,000 tons, compared with the target of 500,000 tons. Speaking at a ceremony in Edinburgh in connection with the presentation of the Mitchell Hedges trophy, Sir Charles Reid, production director of the Board, said that over one-third of the disputes in the industry were occurring in Scotland, which was producing only one-eighth of the total United Kingdom output. Lord Balfour, from the same platform, pointed out that, in February and March this year, 101 unofficial stoppages with a loss of 20,581 manshifts occurred in the Division, as against 52 involving 7,321 manshifts in the last two months of 1947. He described these strikes as a matter of grave concern, more especially in view of the fact that there was available speedy and efficient conciliation machinery. With the exception of graded sorts fuel is adequate for industrial purposes. The marketing authorities are arranging additional supplies for continuous-process users during the pit holidays on May 3 and 4. The coke-ovens are receiving particular attention in view of the current high throughputs. The railways are also receiving extra fuel, which will be met from domestic supplies, the latter being replenished from opencast deliveries. The available surplus for export remains below expectations, but fairly regular shipments are still being made from Methil to Sweden, Denmark and Finland. France is taking Lanarkshire low-volatile gum, and two shipments aggregating 3,500 tons were loaded at Grangemouth this week.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Iron and Steel.—Strong complaint has arisen again from the agricultural steel trades of Sheffield that they cannot get sufficient high-carbon steel to enable them to execute pressing orders for machine parts needed for this year's harvest. Users state that more low-carbon steel has been made at the expense of the output of high-carbon steel which entails longer processes and smaller tonnages. Generally, there is great activity in all branches of the iron and steel trades, the only limiting factor being shortage of some materials. Heavy-engineering branches are heavily booked, and production will be further increased as more machine tools become available. Firms that have undertaken the manufacture of excavating machinery for opencast coal working continue to make very satisfactory deliveries. Some large-scale reconstruction and mechanisation in the light-casting departments have been carried out, and others are being undertaken. Makers of engineers' small tools report a very heavy demand, and there is a continuous call for all types of edge tools.

South Yorkshire Coal Trade.—The shotfirers' strikes have reduced available supplies of coal; work has now been resumed at most pits, but the men are still dissatisfied with their position and complain of weak-willed national leaders. Special efforts have had to be made to minimise delays to vessels awaiting coal cargoes at Hull and Immingham. More coal is being directed to the railways, and numerous lorries which have been doing road haulage of coal are idle. More opencast coal is being used on the steam- and house-coal markets, to permit the best qualities of steam and gas coal to be sent abroad. There are many complaints of poor quality of coal, both from opencast sites and deep mines.

CRUCIBLE AND TOOL STEEL ASSOCIATION: ERRATUM.—In our "Personal" column on page 370, we gave the address of the Crucible and Tool Steel Association as Corn Exchange Buildings, Sheaf-street, Sheffield, 2. We have been informed, however, that the Association are now at 66, Bridge-street, Sheffield, 3.

NOTES FROM THE SOUTH-WEST.

CARDIFF, Wednesday.

Welsh Coal Trade.—Further activity in the export trade, during the past week, has resulted in the hold-up in allocations for shipment caused earlier in the month by the Easter Holidays to be offset. Hence, deliveries during April should be well up to the level of recent months. In the past week, shippers have again experienced a bigger demand than they could cope with, although unusual business arranged was in respect of a cargo of about 1,300 tons for delivery to Switzerland. In addition, two cargoes were booked for West Italy, and shipments were proceeding steadily on the basis of recent levels to Argentina, Portugal, France and Eire. During the week there was considerable activity for the foreign coaling stations, and cargoes were arranged for delivery at Gibraltar, St. Vincent, Las Palmas and Freetown; further shipments were under negotiation. Outputs from the mines have been maintained steadily. The latest figures available showed that the amount of saleable coal raised in the coalfield, during the week ended April 17, was 457,800 tons. Shippers were hopeful that with the usual slackening in demand which becomes apparent at about this time of the year larger quantities would be made available for export. As yet, however, the inland trade is still active and accounted for a large proportion of the coal available. Order books for some of the better sorts are well filled for a long period ahead. Cokes and patent fuel continued to attract a good deal of interest, but supplies were difficult to secure for prompt delivery.

Swansea Steel-Sheet Industry.—The market report issued by the Incorporated Swansea Exchange states that, last week, matters were quieter in regard to new business in tin-plate, and sales to home consumers were below the average. On the other hand, the export market was more active and appreciably increased numbers of orders were placed. Steel sheets continue unchanged; the demand remains exceptionally strong, and makers find difficulty in coping with the many orders offered. Scrap iron and steel is in urgent demand and efforts are being made to increase the deliveries to the works.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

General Situation.—Iron and steel producing plants are as busily occupied as conditions warrant and continued great activity at works over the second quarter of the year is assured; the distributable tonnage, however, is insufficient for customers' requirements. The advance of 1*s.* 2*d.* per shift conceded to blast-furnacemen and steelworkers appreciably increases the cost of iron and steel production, but a rise in the recognised market values is not considered likely. The wage advance, based on cost of living, has been earned by increased productivity, and employers will derive some benefit by reduction in overhead charges. There is still an inconvenient shortage of pig iron and scrap and larger quantities of hard coke are wanted to enable idle blast-furnaces to be re-kindled, but the yield of Cleveland ironstone is more satisfactory than it has been for some time and imports of high-grade foreign ore are maintained at a rate that covers users' requirements.

Foundry and Basic Iron.—Stringency in cast-iron scrap and pig iron continues seriously to affect operations at foundries turning out commodities in demand for home purposes and for export. The tonnage of scrap and pig iron held at the consuming works are at record low levels. The make of basic iron may be further increased in the near future but as yet the output is barely sufficient for current requirements. The demand for good steel scrap is still greater than merchants can meet at the present time.

Hematite, Low-Phosphorus and Refined Iron.—East Coast hematite firms are meeting the essential requirements of their regular customers and the outputs of low- and medium-phosphorus grades of iron are sufficient for the users' actual needs; the production of refined qualities of iron is being maintained on a satisfactory level.

Manufactured Iron and Steel.—Semi-finished and finished iron makers have sufficient bookings to keep their plants fully occupied during the current quarter, and steel manufacturers are well sold, but the intimation of a cut in the steel export target was a great shock to the market after recent disclosures of record steel production. Semi-finished steel continues in strong demand. Reasonably good parcels of heavy blooms and slabs are reaching the rolling mills, but re-rollers are still pressing for larger parcels of light billets and sheet bars. Manufacturers of black and galvanised sheets are turning out heavy tonnages and makers of plates, angles, joists, sections and similar products are maintaining outputs at a high level.

NOTICES OF MEETINGS.

It is requested that particulars for insertion in this column shall reach the Editor not later than Tuesday morning in the week preceding the date of the meeting.

SOCIETY OF ENGINEERS.—Monday, May 3, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "The Development of the Jet Propulsion Engine," by Mr. W. T. Winter.

CHEMICAL SOCIETY.—Monday, May 3, 6.30 p.m., Chemistry Department, University, Leeds. "The Valence of Metals and the Structure of Intermetallic Compounds," by Professor L. C. Pauling. Thursday, May 6, 7.30 p.m., Royal Institution, 21, Albemarle-street, W.1. "The Molecular Orbital Theory of Valency," by Sir John Lennard-Jones, F.R.S.

INSTITUTION OF ELECTRICAL ENGINEERS.—*South Midland Centre:* Monday, May 3, 6 p.m., James Watt Institute, Birmingham. Kelvin Lecture: "The Nervous System as an Electrical Instrument," by Dr. B. H. C. Matthews, F.R.S. *North-Western Centre:* Tuesday, May 4, 6 p.m., Engineers' Club, Manchester. Annual Meeting. "Load Dispatching with Special Reference to the British Grid System," by Mr. A. R. Cooper. *North Midland Centre:* Tuesday, May 4, 6 p.m., Electricity Department, Whitehall-road, Leeds. Annual Meeting. *London Students' Section:* Tuesday, May 4, 7 p.m., Savoy-place, Victoria-embankment, W.C.2. "Heavy Duty Cartridge Fuses," by Mr. K. C. Pounds. *Radio Section:* Wednesday, May 5, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. (i) "Carrier Frequency Shift Telegraphy," by Messrs. R. Ruddlesden, E. Forster and Z. Jelonek. (ii) "Some Developments in Communication Point-to-Point Radiotelegraphy," by Mr. J. A. Smale. *Southern Centre:* Wednesday, May 5, 6.30 p.m., Council Chambers, Portsmouth. "Rural Electrification: The Use of the Single-Phase System of Supply," by Mr. J. S. Pickles. *Installations Section:* Thursday, May 6, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Short papers. *Measurements Section:* Friday, May 7, 5.30 p.m., Savoy-place, Victoria-embankment, W.C.2. Discussion on "The Application of Instruments to Power Station Operation."

INSTITUTION OF CIVIL ENGINEERS.—Tuesday, May 4, 5.30 p.m., Great George-street, S.W.1. "Problems in the Selection of Sites for Civil Airports and Military Air-Stations," by Mr. W. J. Cozens. *North-Western Association:* Thursday, May 6, 6.30 p.m., Engineers' Club, Manchester. Annual Meeting. "Swedish Bridge Construction and the Sandö Bridge," by Mr. Sven Klingberg (with film).

CHEMICAL ENGINEERING GROUP.—Tuesday, May 4, 5.30 p.m., Geological Society, Burlington House, Piccadilly, W.1. "Modern Propellants Employed in British Ordnance," by Dr. J. N. Pring.

IRON AND STEEL INSTITUTE.—Royal Institution of Chartered Surveyors, 12, Great George-street, S.W.1. Annual General Meeting. Wednesday, May 5, 9.45 a.m., Presidential Address and Discussion; 2.30 p.m., Discussions; 8.30 p.m., Hatfield Memorial Lecture. Thursday, May 6, 9.30 a.m., Discussions. For programme, see page 346, *ante*.

INSTITUTION OF WATER ENGINEERS.—Guildhall, Southampton. 53rd Summer General Meeting. Wednesday, May 5, 10 a.m., (i) Presidential Address by Mr. Joseph Hawksley. (ii) "River Itchen Supply," by Mr. C. A. Bradley; 2 p.m., (i) "Economics of Pumping," by Mr. G. W. Fuller. (ii) "A Year's Experience with Micro-Straining," by Messrs. F. P. Hornby and F. H. Thomas; 8.15 p.m., Reception. Thursday, May 6, 1.30 p.m., trip to Otterbourne Pumping Stations and River Itchen Intake. Friday, May 7, 9.20 a.m., visit to Southampton Docks.

ROYAL SOCIETY OF ARTS.—Wednesday, May 5, 2.30 p.m., John Adam-street, W.C.2. "Recent Advances in Stereochemistry," by Dr. F. G. Mann, F.R.S. Thursday, May 6, 2.30 p.m., "Tatas: Sixty Years' Industrial Development in India," by Sir Frederick E. James.

JUNIOR INSTITUTION OF ENGINEERS.—*Midland Section:* Wednesday, May 5, 6.30 p.m., James Watt Institute, Birmingham. "Domestic Gas Appliances," by Colonel H. S. Walter. *Institution:* Friday, May 7, 6.30 p.m., 39, Victoria-street, S.W.1. "Technical Evidence: Some Reminiscences," by Mr. W. A. Tookey.

INSTITUTION OF PRODUCTION ENGINEERS.—*Nottingham Section:* Wednesday, May 5, 7 p.m., Victoria Station Hotel, Milton-street, Nottingham. Lecture on "Metal Finishing."

INSTITUTION OF MECHANICAL ENGINEERS.—*London Graduates' Section:* Thursday, May 6, 6.30 p.m., Storey's-gate, St. James's Park, S.W.1. Annual Meeting. "Motion Study and the Mechanical Engineer," by Mr. P. R. L. Bennett.

DIESEL-ELECTRIC SHUNTING LOCOMOTIVE.

(*For Description, see Page* 416.)

FIG. 3. LOCOMOTIVE IN SERVICE.

FIG. 4. LOCOMOTIVE BEING ERECTED.

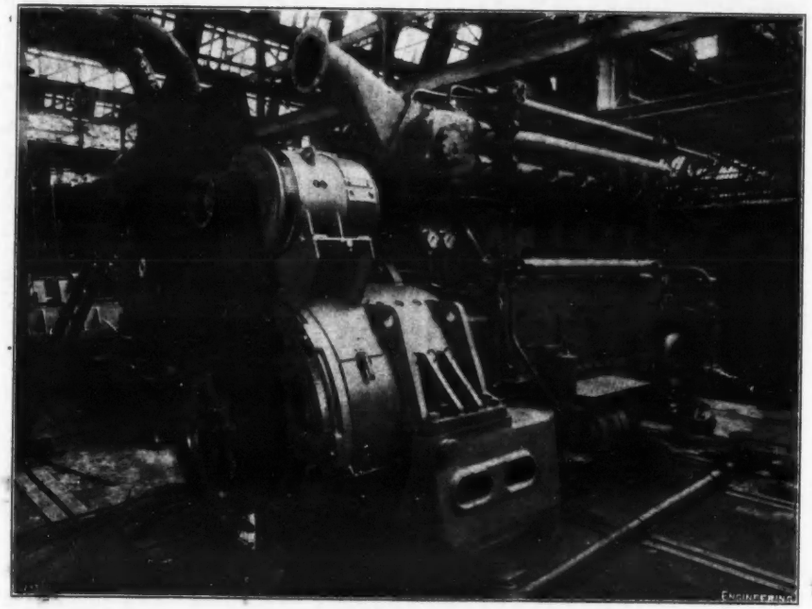


FIG. 5. MAIN AND AUXILIARY GENERATORS.

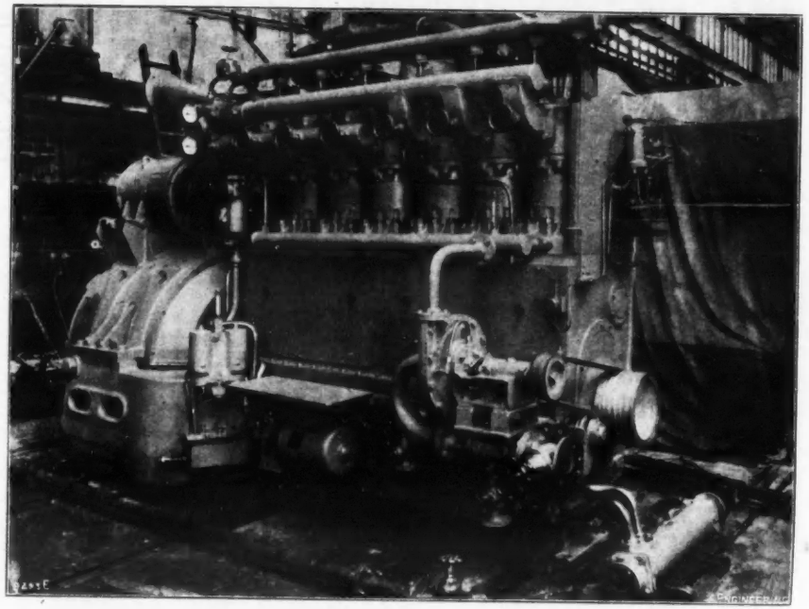


FIG. 7. GENERAL VIEW OF POWER PLANT.

ENGINEERING.

35 & 36, BEDFORD STREET, STRAND, LONDON, W.C.2.

We desire to call the attention of our readers to the fact that the above is the address of our Registered Offices, and that no connection exists between this Journal and any other publication bearing a similar title.

Telegraphic Address:
"ENGINEERING," LESQUARE, LONDON.

Telephone Numbers:
TEMPLE BAR 3663 and 3664.

All editorial correspondence should be addressed to the Editor and all other correspondence to the Manager.

Accounts are payable to "ENGINEERING," Ltd. Cheques should be crossed "The National Provincial Bank, Limited, Charing Cross Branch." Post Office Orders should be made payable at Bedford Street, Strand, W.C.2.

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"ENGINEERING" may be ordered from any newsagent in town or country and from railway bookstalls, or it can be supplied by the Publisher, post free, at the following rates, for twelve months (or for six or three months, *pro rata*), payable in advance:—

For the United Kingdom and all places abroad, with the exception of Canada	£4 10 0
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ADVERTISEMENT RATES.

Terms for displayed advertisements on the green art paper wrapper, on the inside black and white pages and in the buff art paper two-colour supplement, as well as for inserts, can be obtained on application to the Manager. The pages are 12 in. deep and 9 in. wide, divisible into four columns 2¼ in. wide. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

The charge for advertisements classified under the headings of "Appointments Open," "Situations Wanted," "Tenders," etc., is 8*s.* for the first four lines or under, and 2*s.* per line up to one inch. The line averages six words and when an advertisement measures an inch or more, the charge is 24*s.* per inch. If use is made of a box number the extra charge is 1*s.* per insertion, with the exception of advertisements appearing under "Situations Wanted." Series discounts for all classified advertisements can be obtained at the following rates:—5 per cent. for six; 12½ per cent. for thirteen; 25 per cent. for twenty-six; and 33⅓ per cent. for fifty-two insertions.

TIME FOR RECEIPT OF ADVERTISEMENTS.

Classified advertisements intended for insertion in the current week's issue must be received not later than first post Wednesday.

"Copy" instructions and alterations to standing advertisements for display announcements must be received at least 10 days previous to the date of publication, otherwise it may be impossible to submit proofs for approval.

The Proprietors will not hold themselves responsible for advertisers' blocks left in their possession for more than two years.

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ENGINEERING

FRIDAY, APRIL 30, 1948.

VOL. 165. No. 4292.

THE NATIONALISATION OF INVENTION.

THERE can be few better illustrations of the proverb that "Appetite comes with eating" than the progress of nationalisation in any country where this principle has obtained a firm hold; or perhaps it should be said, where the principal protagonists and beneficiaries of a policy of nationalisation have secured such a hold as to grudge to free enterprise the retention of independent control over any activity which might show signs of being profitable. Hitherto, however, it has been accepted that an inventor might be allowed a limited period of personal monopoly in the fruits of his own inventiveness; not with the intent that he should be encouraged to exploit it to his financial advantage, by way of incentive to invent, but rather on the tacit understanding that an inventor is the best person to be trusted to develop his invention to the point of providing the community in general with an additional asset. This, perhaps, is rather a modern view of the matter, since there appears to be little doubt that the exclusion of monopolies for invention from the fundamental Statute of Monopolies of James I was intended primarily, in the words of one commentator,* as a reward "for augmenting public knowledge by scientific discoveries"; to-day there is probably a more general recognition that, while no amount of prospective reward can induce invention, as distinct from development, no consideration of the paucity of reward will prevent the naturally inventive mind from inventing. In modern circumstances, however, it is becoming progressively more difficult and unlikely that any invention, as initially conceived, will be practically usable without the expenditure of much thought (and probably much money) on a relatively laborious period of development; and an inventor may well be deterred from undertaking this development unless he is assured of a chance to recoup himself.

In recent years, the increasing proportion of patentable ideas which arise in the course of the inventor's employment, and the extent to which their development must be financed by the employer (whether an individual, a firm, or a public authority or Government department) if they are to be developed at all, have introduced new factors of considerable influence. Many of these ideas are of such a nature that they would be virtually valueless to the original inventor, even if he were granted an absolute right to them, because no private individual could support the outlay needed to bring them to a usable condition. Others again possess the general characteristic that they have arisen indubitably out of the individual's employment as a servant of the State, are *ab initio* in the category of State secrets, and, while possibly of the highest importance as such, would be valueless elsewhere except, perhaps, as something which might be sold to another State; a new type of shell fuze, for example, would come into this general classification.

Such inventions as the last-mentioned type are obviously of a kind over which the State must exercise a firm control, and hitherto the problems of obtaining and maintaining that control have been regarded as sufficiently answered by various enactments, or regulations having the force of law, the general purport of which is well understood by those who are likely to be affected by them. The extension of nationalisation, however, has enlarged immensely the proportion of the population which, by reason of its employment, is not free to exploit an individual invention for the benefit of the inventor or at all, or to sell it to others who might be in a better position to do so. The development of Governmental activities in various fields of applied science, too, has the effect of bringing into this class of persons who may invent but may not exploit their inventions a large number of the trained engineers and men of science who, by reason of their training, are well above the average in their probable fertility of mind. It is clearly in the national interest that their inventive faculties should be encouraged rather than restricted.

Out of some such line of argument as this, it is evident, has evolved the Development of Inventions Bill, now before Parliament, and in principle, at any rate, there is much to be said for it; but whether the approval which may be extended to the principle is equally well deserved by the proposed method of putting it into practice is debatable, and the wider powers which have been tacked on to the initial framework of the Bill appear to go a long way beyond any proven necessity. The Bill is described in the preamble as "An Act to establish a national corporation for securing the development and exploitation of inventions; to authorise advances to the corporation out of the Consolidated Fund and, in respect of certain services, payments to the corporation out of moneys provided by Parliament; and for matters connected therewith." As happens so often, the sting is in the tail.

That there should "be established . . . a body corporate to be called the National Research Development Corporation" seems an innocuous proposal enough; nor can serious exception be taken (unless with regard to a certain vagueness inherent in the phrase "where the public interest so requires") to the Corporation's primary functions "of securing . . . the development or exploitation of inventions resulting from public research" or its secondary purpose "of acquiring, holding, disposing of and granting rights (whether gratuitously or for consideration) in connection with inventions resulting from public research." What is likely to cause apprehension among inventors, and among all those who have now learned by experience how (to take some liberty with the metaphor) the little finger of an Act of Parliament may be thicker than its apparent loins, is the extension of the first function to "any other invention as to which it appears to the Corporation that it is not being developed or exploited or sufficiently developed or exploited"; and of the second function to "inventions resulting from other sources." Lest it should be found that even these all-embracing clauses are not sufficiently comprehensive, it is laid down that "In this Act, the expression 'invention' includes any new process or new technique"; an omnibus clause which, apparently, extends the grabbing powers of the Corporation even to processes and techniques that are not in themselves patentable.

The details of the constitution of the proposed Corporation, the qualifications of its chairman, managing director and other members, and the

* G. W. Tookey, "Legal Protection for Originality," *Jl. Jun. Inst. of Engineers*, vol. 39, page 123 (1928-9).

schedule governing their remuneration and tenure of office are relatively immaterial by comparison with the sweeping nature of their prospective powers; though it is of some interest to note that, as a body, the Corporation is expected to be financially self-supporting "as soon as may be" after its establishment and "taking one year with another." As usual, however, this requirement is qualified by a fairly generous "escape clause," providing that "the Minister in charge of the department" (presumably the Board of Trade, though this is not absolutely certain) "may, with the consent of the Treasury, make . . . out of moneys provided by Parliament payments to the Corporation in respect of any loss or estimated loss arising or likely to arise." Temporary borrowings are sanctioned up to an aggregate amount of 250,000*l.*; and, to meet capital expenditure and initial expenses, the Board of Trade may, with the consent of the Treasury, make advances to the Corporation up to a total of 5,000,000*l.* within the first five years of its existence.

The Bill is not a long one—the whole of it, including the schedule dealing with the remuneration of the members and staff of the Corporation, is contained in eight pages—so that it may be read slowly and carefully in a comparatively short time. We have read it from end to end more than once, and the more significant passages several times, but nowhere do we find a word about the rather important matter of remunerating or compensating the inventor, though there are references to the possibility of payments to persons engaged in developing inventions. Section 1 would empower the Corporation "to carry on any activity the carrying on of which appears . . . to be requisite, advantageous or convenient," and, in particular, to "carry on, or promote or facilitate the carrying on by other persons, of any business." The fact that the approval of the Board of Trade would be required for, among other purposes, "the provision of financial assistance to any person undertaking the development or exploitation of any invention" clearly indicates the intention to make such provision; but it does not follow necessarily that the person who undertakes the development or exploitation is the inventor. For all that the Bill contains to the contrary, it would seem that it offers to the inventor who is not personally concerned with the development or exploitation (or who is excluded from active participation, as some might have to be if real progress is to be made) no expectation of anything but an *ex gratia* payment unless he is prepared to incur the expense of legal proceedings.

It almost appears as though, when originally drafted, the Bill was designed to apply only to inventions by employees of Government departments or State-sponsored and State-controlled authorities, and that the extension of its scope to include any other invention or activity was an afterthought, born of the draftsman's desire not to exclude inventions and enterprises which he lacked the ability to define precisely, but which might conceivably be associated, even indirectly, with State-controlled activities. As it stands, however, the wording of the Bill does seem to afford considerable latitude for the virtual expropriation of an invention, even though the inventor may not be in Government employ, and for the application of the technique to which we have alluded on a former occasion, by making it practically impossible for the inventor himself to develop or exploit his invention and then acquiring it forcibly on the ground that he had failed to do so. Objections to the inclusion of sweeping powers in other Bills, based on an expressed fear that they might be used unfairly, have been met in Commons debates by the deprecatory assurance that "the Minister would never use his powers in that way"; but even a Minister of the Crown cannot bind his successors very effectively, and the clause in the Bill which states that "anything authorised or required . . . to be done by, to or before the Board of Trade may be done by, to or before the President of the Board, any secretary, under-secretary or assistant secretary of the Board, or any person authorised in that behalf by the President," seems to offer unduly wide opportunities for the exploitation of the inventor as well as the invention.

THE ADMINISTRATION OF PORTS.

WHEN a river enters the sea, the velocity of the water is checked and the coarse material carried in suspension sinks to the bottom. Silt and fine mud are carried farther out, but to a considerable extent they are also ultimately deposited. This process tends to increase the area of the land, which, however, may at the same time be decreased by sea erosion in other places. On the whole, it is considered that the total area of Great Britain is being enlarged, rather than reduced, by these and other natural actions, but this may be little satisfaction to those concerned with some port, situated on an estuary, which is gradually being rendered inoperative by the silting of the river. The small town of Parkgate, on the north bank of the River Dee, was a port of importance in the Thirteenth Century, but is now about two miles from the stream bed. There are many other cases and even such an important port as Grimsby was so affected by the silting of the tidal stream that from an important trading centre in the Middle Ages it shrank to a small village. The port was re-opened in 1800 as a result of dredging "paid for out of money publicly subscribed by certain local gentlemen, and docks and other works were constructed." Since that time, the port of Grimsby has flourished.

Presumably in the future "certain local gentlemen" will be relieved from the necessity of activities of this kind, which will fall within the province of the British Transport Commission. That body will have to make important decisions. In a paper entitled "The Future of British Ports and Canals," read before the Institute of Transport on April 12, Mr. W. A. Flere stated that there are about 350 places in Great Britain each of which "could be called a harbour or a port." Of these, more than 50 are privately owned and in most cases handle the mineral, or other product, of some commercial company. Of the remaining ports, it is estimated that about 140 cannot handle vessels above 500 tons alongside berths, and a further 80 are restricted to vessels of 1,000 tons. These two classes, available only for the smaller coasters, accordingly make up some two-thirds of the total. There is, however, a tendency to increase the size of coasters in order to improve the ratio of deadweight carrying capacity to displacement weight. For a small coaster this is about 0·5, as compared with 0·75 for a freighter of 8,000 gross tons.

No doubt some, or many, of the smaller ports could be adapted to deal with larger vessels, but a decision on the matter is no longer the concern of local interests; it falls within the ambit of the British Transport Commission. This omnivorous body has not absorbed coastal shipping in its digestion of the railways and road transport but its control of the ports will enable it to bring considerable pressure to bear on that industry. The older ports were established and developed to serve contiguous areas of country at a time when land transport was in a primitive state of development and water transport, by river or sea, was the only effective agency for moving goods in bulk. Much work was carried out in early days and the Aire and Calder Navigation was established as long ago as 1698. It may well be that, in the terms of to-day, local interests established too many ports in the past. In 120 miles of coastline of the Firth of Forth there are 30 ports, 18 of which are able to deal with coasters up to 1,000 tons gross, and in England as a whole, there are ports or harbours of some kind in every 15 miles of coastline.

Many of the ports on the Firth of Forth were originally established to handle coal from the Fife and Lothian coalfields and, quite apart from any question of port equipment, it is clear that the development of rail and road transport may have rendered some of them redundant. Many small ports in various parts of Great Britain are far from prosperous and it may well be that the Transport Commission may decide to develop and improve selected examples and abandon others. A policy of this kind might be economically sound and yet adversely affect many local interests. The question of the smaller ports forms but a small item in the mass problem with which the Commission has to deal, and it is to be hoped that it will be given adequate attention in any broad plans which are evolved. Water transport is cheaper than that by either rail or road and policies designed to foster the latter two might not represent over-all economy. Mr. Flere stated in his paper that "the difficulty of obtaining wagons has diverted much of the lower grade import and export traffic from railways to waterborne or coaster transport" and it would be profitable to consider if this forced policy might not usefully be adopted as a deliberate one. Mr. Flere also referred to the development of canals, which is an important item in the whole question of waterborne transport. He said "no ground exists at the present time for regarding any inland waterway as obsolete unless it serves a worked out mineral area or a dying industrial area." There are many existing canals and regulated rivers to which these latter conditions do not apply. To bring some of them into a co-ordinated inland water transport scheme, widening and improvement would be necessary. Mr. Flere adds, "the crux is the capital which must be spent," but the new Commission should be in a better position to face this aspect of the problem than were the various bodies they have superseded.

For the general administration of ports, both small and large, Mr. Flere suggested that eight area boards should be set up. These would deal with all ports in their respective sections of coastline. As an example, the Southern Area would cover all ports from Ramsgate to the estuary of the River Exe, including the Isle of Wight. These ports serve a population of about 3 million, which is steadily increasing. One of the tasks of the boards, or the Commission, will be to introduce greater uniformity into the administrative practice pursued. For instance, for goods shipped via Liverpool, no export handling charges are payable, whereas in London, a wharfage and porterage charge is made. It is also suggested that obligations which have been imposed on various harbour directorates, such as the supervision of river pollution and the running of passenger ferries, should be handed over to other bodies, since they are not proper functions of port management. Mr. Flere defines the main duty of his proposed boards as seeking "to help the better physically and industrially placed ports in every way," . . . seeking "to divert trade to them and away from the smaller and more expensively maintained ports, removing equipment therefrom if they were of opinion it could be put to better use elsewhere." Earlier remarks in this article have some bearing on this definition of functions.

There is little doubt that the problem to which the Transport Commission, or the boards, if they come into existence, could most usefully direct immediate attention is improvement in the rate of turn-round of shipping. The present unsatisfactory standard of performance, which is not confined to this country, is due, to an important extent, to the fact that mankind has decided that the period following years of unexampled material destruction is a good time to do less work. That material destruction certainly hampers present performance, but it is not the sole reason for the fact that turn-round at Beira now takes 90 days and a similar operation in British ports, about a fortnight, as Mr. Flere might appear to suggest. He states that "practically all the trouble is due to the non-clearance of the port warehouses and sheds owing to lack of railway wagons, locomotives and barges." Many warehouses and sheds were destroyed during the war and are not yet rebuilt and their absence aggravates the difficulties of clearing material. Their rehabilitation is a question of capital expenditure as well as materials and labour and an early easing of the situation does not seem probable.

The question of shortage of railway rolling stock is certainly being dealt with energetically and considerable improvement should be seen in the course of the next few years, but in ports, as in many other spheres of activity, material equipment will long remain at a level lower than is desirable and improvement in performance will have to depend mainly on the full utilisation of what is available.

NOTES.

THE INSTITUTION OF ELECTRICAL ENGINEERS.

PROCEEDINGS at the meeting of the Institution of Electrical Engineers on Thursday, April 22, began with the presentation of certificates of honorary membership to Admiral of the Fleet Sir John Cunningham, G.C.B., M.V.O., and Col. Sir T. F. Purves, O.B.E. In making the presentation to Sir John Cunningham, the President (Mr. P. Good, C.B.E.) explained that, by a new by-law, the Council were now empowered to elect every three years, as honorary members, eminent persons who were not already members of the Institution, in addition to the one honorary member who may be elected each year and upon whom no such restriction is placed. It was fitting, he said, that Sir John Cunningham, who had played so outstanding a part in stimulating the application of electrical technique in the Royal Navy, should be the first to be admitted under the new arrangements. In reply, Sir John thanked the Institution for the honour conferred upon his great Service and, in particular, for the tribute paid to the Electrical Branch. The Navy had received enormous help from electrical engineers, especially in the development of degaussing, the non-contact torpedo and radar. Sir Thomas Purves, who also replied, said that he looked back on his long connection with the Institution with unalloyed pleasure. It was a delight to old members, like himself, to see how fairly and squarely they were being left behind by the younger men in the new fields into which penetration was being made. The President then presented the Faraday Medal for 1948 to Professor M. L. E. Oliphant for his distinguished work in nuclear physics and for his original discoveries in physical science, particularly in the realm of electromagnetic oscillations. In returning thanks, Professor Oliphant said that he looked upon the award as a tribute to the workers in his laboratory, especially in the early days of the war, when it was considered an achievement to be able to detect aircraft at a range of 10 miles. All the work that had been done in nuclear physics was the fruit of Rutherford's genius and he was proud that the award of this medal linked him still more closely with that great pioneer. After the Cooper's Hill Memorial Prize had been presented to Mr. E. C. Cherry, the thirty-ninth Kelvin lecture, on "The Nervous System as an Electrical Instrument," was delivered by Dr. B. H. C. Matthews, C.B.E., F.R.S. In the course of his remarks, the lecturer gave an historical account of the work that had been done in this field since the days of Hawksbee, Galvani and Faraday, and pointed out that animal cells were the source of current at potentials which generally did not exceed 100 mV, although values as high as 500 volts were obtained from the South American eel. On the other hand, the voltage gradient was as steep as 1,000 volts per centimetre, and the phenomenon could not therefore be regarded as negligible. The pulse that was generated at 40 to 50 mV by muscular action and passed along the nervous fibres, did not, however, last for more than 1-1,000 second and measurement was therefore not easy, although the invention of the thermionic valve and the cathode ray tube had facilitated matters.

RESEARCH ON FUEL INDUSTRIES AT LEEDS.

The first post-war session of the coal-gas, fuel-industries and metallurgy department of the University of Leeds was a period of substantial progress; freed from many of their war-time commitments, members of the staff were able to give their undivided attention to teaching and research. The report covering the work of the session, that for 1945-46, has just come to hand and it is stated therein that it was presented to the Coal Gas and Fuel Industries Committee of the University on June 2, 1947. The report records briefly the appointment of Professor D. T. A. Townend as Director of Research to the British Coal Utilisation Research Association and his consequent resignation of the Livesey Professorship of Coal Gas and Fuel Industries in September, 1946; and the appointment to the Livesey Chair of Dr. A. L. Roberts with effect from January 1, 1947. The Joint Research Committee of the Gas Research Board and the University of Leeds is shown to be concerned henceforth mainly with long-term and fundamental work on the catalytic synthesis of methane, the catalytic removal of organic sulphur compounds from gases, the purification of gasworks liquor effluents, and radiant heating. Experimental work on the removal of the organic sulphur compounds from synthesis gas has resulted in a process which enables the sulphur content to be reduced to 0·001 grain per 100 cub. ft. In connection with the work on gasworks liquor it is stated that one of the most objectionable constituents of the liquor is ammonium thiocyanate and experiments are being carried out to determine the mechanism of its formation in gasworks scrubbers, with the object of effecting some reduction in the thiocyanate content of liquor effluents. Other researches carried out in the Department concern coal and coke, coal tar, the overheating and "burning" of steel and other metallurgical problems, the transfer of energy from flame gases to solids, the stability of burner flames, the rate of spread of fire, the measurement of flame speeds at high pressure, and refractories. In co-operation with the British Refractories Research Association, work has been continued on the clay-quartz system, and further studies have been made on the fundamental changes taking place in siliceous refractories on continued exposure to high temperature.

THE INSTITUTION OF MECHANICAL ENGINEERS' BENEVOLENT FUND.

The 36th annual general meeting of members of the Incorporated Benevolent Fund of the Institution of Mechanical Engineers was held at the Institution, Storey's-gate, St. James's Park, on April 16, the chair being taken first by Lord Dudley Gordon, who presented the report of the Committee of Management for 1947, and subsequently by Major William Gregson, the new President of the Institution. The committee drew attention to the increasing distress arising from the war, and the fact that this was felt not only by the older members, many of whom found it difficult to obtain employment, but also by younger men, whose savings sometimes proved insufficient to tide them over periods of illness. Because of the higher cost of living, allowances previously considered reasonable had had to be increased. It was doubtful, in the committee's opinion, whether finality had yet been reached in this direction. The President's centenary appeal reached a total of 3,631*l.* by the end of 1947, and subsequent donations had brought this figure up to 4,000*l.*; this appeal, it was added, was still open. The number of members of the Benevolent Fund, however, was still less than 20 per cent. of the total membership of the Institution, and whereas, in 1946, it had been possible to transfer 400*l.* from revenue to the Income Reserve Account, in 1947 it was necessary to draw on this account to the amount of 85*l.* The committee therefore appealed to non-contributors to become members of the Benevolent Fund, preferably by subscribing to it under deeds of covenant.

THE BRITISH ELECTRICAL AND ALLIED MANUFACTURERS' ASSOCIATION.

The report of the British Electrical and Allied Manufacturers' Association for 1947-48 begins by recording the death of the Earl of Derby, who had been president for twenty-six years. Turning to the trade position, it is pointed out that output in 1947 was handicapped by shortages of labour, materials, components and capital equipment. Labour requirements are still not being met in spite of the fact that during 1947 308,000 men and 194,000 women were being employed, representing increases, respectively, of 7·5 and 1·4 per cent. over the figures of the previous year. To alleviate the shortages of materials, which it was thought might become particularly severe in those products not covered by Government priorities, it was arranged to make an assessment of the amounts of basic materials required in 1948, 1949 and 1950; to keep the industry working as a balanced entity. A questionnaire covering 65 different materials was therefore sent to all member firms and the information thus collected was submitted to the Ministry of Supply and the Board of Trade. Direct contact with the producing Associations was also established so that their output plans could be matched with the electrical industry's demands. A Materials Committee has been appointed to put this policy into effect. Certain of the Government's proposals for the reduction of capital expenditure are viewed with concern, as the Association is convinced that any drastic economy of this kind in an industry, such as electrical manufacture, may be a serious obstacle to the maintenance of its pre-eminent position in the export trade. The importance of this branch of the Association's activities is indicated by the statement that in 1938 the United Kingdom was the largest exporter of electrical goods in the world, the value being about 23,000,000*l.* After the war, further rapid progress was, however, made and, in 1947, the value reached was about 72,000,000*l.* It is calculated that this represents an increase of 66 per cent. over the 1938 volume. The expansion was considerable in nearly every product. In fact, the number of house-service meters exported was more than double that of 1938, with a value exceeding 1,000,000*l.*, and the value of the X-ray equipment exported increased by ten times during the decade. In electrical machinery 69,400 tons were exported in 1947, compared with 44,600 tons in 1938, an increase of 55·5 per cent. Switchgear also increased from 9,700 to 11,600 tons.

BRITISH ASSOCIATION.

As already announced in our columns, the 110th annual meeting of the British Association will be held at Brighton, the dates being from Wednesday, September 8, until Wednesday, September 15. The preliminary programme of the meeting has now been issued and this states that the inaugural meeting will take place in the Dome, at 8.30 p.m., on September 8, when the Mayor of Brighton will welcome the Association and the President, Sir Henry Tizard, K.C.B., F.R.S., will deliver his presidential address on "The Passing World." Other evening addresses will be delivered by Professor S. W. Wooldridge, Viscount Samuel and Professor J. D. Bernal, F.R.S. The general secretaries of the Association are Dr. Edward Hindle, F.R.S., and Sir Richard Southwell, F.R.S. The President of Section G (Engineering) is Wing-Comdr. T. R. Cave-Browne-Cave, C.B.E.; the recorder, Professor Willis Jackson, City and Guilds College, South Kensington, London, S.W.7; and the secretary, Mr. D. H. McPherson. Meetings of the Section will be held in the Royal Pavilion. The President of Section A (Mathematics and Physics) is Sir Lawrence Bragg, O.B.E., F.R.S.; the recorder, Dr. Ezer Griffiths, F.R.S., National Physical Laboratory, Middlesex; and the secretaries, Professor R. W. Ditchburn, Mr. R. W. Powell and Professor H. S. Ruse. This section will meet in the Dome and also at the College of Art. The President of Section B (Chemistry) is Professor John Read, F.R.S.; the recorder, Dr. H. J. T. Ellingham, Royal Institute of Chemistry, 30, Russell-square, London, W.C.1; and the secretaries, Professors L. Hunter and W. Wardlaw. This section will hold its meetings in the Royal Pavilion. Visits to the Royal Observatory, Hurstmonceux, Southwick power station, Brighton railway works, Portsmouth Dockyard, and other places of interest are being arranged. Copies of the programme may be obtained from the secretary, at Burlington House, Piccadilly, London, W.1.

THE WORLD'S SHIPBUILDING.

For the first time since December, 1944, the total gross tonnage of the merchant ships of 100 tons and upwards, under construction in Great Britain and Northern Ireland on March 31, showed a decline as compared with the figure for the end of the previous quarter. The decline, however, as is shown in the quarterly returns issued by Lloyd's Register of Shipping, is small, the totals being 2,138,035 tons on March 31, as compared with 2,162,982 tons on December 31, 1947, and the present total is greater by 114,892 tons than the aggregate for March 31, 1947. Moreover, with the exception of the fourth quarter of last year, the total has not been exceeded since March, 1922, when the aggregate steamer and

motorship tonnage recorded was 2,233,498 tons. As in previous quarters, however, the tonnage under construction, at the present time, is influenced by delays imposed by the prevailing circumstances. Nevertheless, during the quarter under review, 233,639 tons of shipping were completed in this country, 213,451 tons were commenced, and 181,168 tons were launched. The tonnage of steamers and motorships under construction in overseas shipyards on March 31 totalled 1,781,339, this being 27,567 tons less than that recorded on December 31, 1947, when it was noted that no figures for Germany, Japan and Russia were included. These reservations still apply. The leading foreign shipbuilding countries were France, which was responsible for 293,675 tons; Sweden, which produced 264,685 tons; Holland, which is building 237,527 tons; and Italy, which has 215,200 tons under construction. All others were responsible for less than 200,000 tons. During the quarter under review 193,857 tons were commenced in overseas shipyards, 211,711 tons were launched and 241,647 tons were completed. Of the total under construction in Great Britain and Northern Ireland at the end of March, 977,941 tons consisted of steamers and 1,160,094 tons of motorships. On the same date, the shipping under construction abroad comprised 445,128 tons of steamers and 1,336,211 tons of motorships. Oil tank steamers and motorships of 1,000 tons gross and upwards now under construction in the world amount to 89 vessels, making together 812,227 tons. Of these, 54 ships, aggregating 493,155 tons, are being built in Great Britain and Northern Ireland; 10 vessels, totalling 105,900 tons, in Sweden; six vessels, comprising 64,986 tons, in Denmark; and five, making together 57,960 tons, in France.

The Junior Institution of Engineers.

The annual dinner of the Junior Institution of Engineers was held at the Connaught Rooms, London, W.C.2, on April 23, the chair being taken by the President, Mr. R. A. Riddles, C.B.E. Mr. W. A. Tookey officiated once again as toastmaster, duly observing the ritual of informal toasts which makes the J.I.E. dinner unique among such institutional functions; and once again the company had the pleasure of drinking to Mr. F. R. Taylor, sole survivor of the small band of youths who founded the Institution in 1884. The toast of "The Institution" was proposed by Major William Gregson, M.Sc., President of the Institution of Mechanical Engineers, who recalled the pioneer work of "the Juniors" in providing for the younger engineers opportunities for technical discussion which, when the Institution was founded, they did not enjoy in any of the senior institutions. Mr. P. W. Dunn, chairman of the Institution, who responded, gave the members some interesting (and hitherto unrecorded) sidelights on its early history, illustrating the great debt it owed to the encouragement of the late Professor (afterwards Sir) A. B. W. Kennedy. In the absence of Engineer Vice-Admiral Sir Harold Brown, Sir William Stanier, F.R.S., proposed the toast of "Engineering and British Railways," which gave Mr. R. A. Riddles the opportunity to pay a tribute to Sir William's work for British locomotive engineering, and also to that of Mr. Tookey during the recent war. In response to the toast of "Our Guests," proposed by Mr. Geoffrey W. Tookey, Major W. H. Morgan, C.B.E., vice-president of the Institution of Civil Engineers, said that the senior institutions had learned a good deal from the Juniors' in the matter of catering for the younger members of the engineering profession. The concluding toast, that of "The Chairman" (Mr. Riddles), was proposed by Mr. S. J. Crispin, vice-chairman of the Institution, and received with the customary and characteristic acclamation.

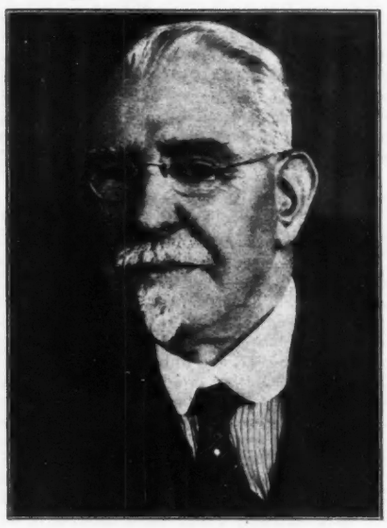
"Principles and Precedents": Erratum.—We regret that an error occurred on page 398, *ante*, in the article with the above title, the words "as being inadequate," in the second paragraph of the first column on that page, being transposed to four lines above their proper place; they should follow the words, "was widely criticised." The mistake does not appear in all copies of the issue of April 23, as it was corrected in the course of printing.

OBITUARY.

SIR WILLIAM REAVELL.

It is with great regret that we record the death on April 25, at his home in Ipswich, of Sir William Reavell, founder of the firm of Reavell and Company and senior past-president of the Institution of Mechanical Engineers. He was 82 years of age.

Sir William, who was born on March 2, 1866, received his schooling and early engineering training on the North-East Coast. He was educated at the grammar school at Alnwick, Northumberland, from 1872 to 1882, and in the latter year entered upon an apprenticeship of five years in the marine engineering works of Hawthorn, Leslie and Company, St. Peter's, Newcastle-on-Tyne, concurrently attending evening classes in Newcastle. On the completion



The Late Sir William Reavell.

of his apprenticeship, he remained with the firm for two more years in their drawing office. In 1889, he obtained a post as a draughtsman with Maudslay, Sons and Field, Limited, at Lambeth, continuing his technical education at the Birkbeck Institute and the Finsbury Technical College. He remained at Lambeth until the close of 1891 and was then appointed to the marine engineering department of Babcock and Wilcox, Limited, the newly-formed English company established by the American originators of the Babcock and Wilcox water-tube boiler. Before long, he was manager of the department, which he continued to direct for six years. In 1897, however, he returned to Lambeth as general manager of the engineering works of Peter Brotherhood, Limited, then in Belvedere-road; but in the following year he decided to start in business on his own account and founded the Ranelagh Works at Ipswich for the purpose of building high-speed steam engines and air compressors.

From the outset, the business of Reavell and Company prospered, the manufacture of air-compressing plant especially, so that eventually engine-building was dropped and the whole works devoted to air compressors, blowers, and similar machinery. The rapid extension in the use of such equipment, and the great variety of new uses which speedily developed, largely as a result of Sir William's pioneer work, were well indicated in his presidential address to the Institution of Mechanical Engineers in 1926—the year in which the membership of the Institution passed the 10,000 mark, an event which was celebrated by a special gathering in London, over which he presided.

Sir William—who received his knighthood in 1938—was also a member of the Institution of Naval Architects and a past-president of the Institution of Engineers-in-Charge. He held the last-mentioned office for two years and, in his two presidential addresses, gave a valuable report on engineering developments in the Far East, which he had visited as one of the two delegates from the Institution of Mechanical Engineers to the World Engineering Congress at Tokyo in 1929. He was President of the British Engineers' Association from 1930 to 1936, and was also a prominent member of the British Standards Institution, being chairman of its Mechanical Industry Committee when it was still the British Engineering Standards Association, chairman of the General Council in 1936, and chairman of the Engineering Divisional Council from 1931 to 1944. He was also a former mayor of Ipswich. To all these activities he devoted himself with a characteristic thoroughness, and with a combination of efficiency and courtesy which will not be forgotten by those who knew him.

THE STORY OF ATOMIC ENERGY.

XII.—PRACTICAL TRANSMUTATION.

By Dr. Frederick Soddy, F.R.S.*

The Two Objectives.

From now on, two distinct objectives, requiring quite different processes, were pursued in the attempt on the large-scale release of atomic energy from uranium. The first, primarily and immediately, was mainly of military importance, to use it as a super-explosive. The second, of more general economic significance, was its gradual controlled release to provide for general purposes a new and unequalled source of power. Both were pursued with equal zest, principally in the United States, from the start, and, because the second soon promised to prove a quicker and better road to the first, right up to the final accomplishment. In the end, both processes seem to have contributed about equally to the military achievement.

The Explosion Objective.

As regards the explosion objective, it was necessary to attempt the separation of the two isotopes, of mass numbers 235 and 238, in the expectation that uranium, if sufficiently enriched in the 235 isotope, would detonate spontaneously under proper conditions. On May 6, 1940, 18 months prior to the Japanese attack on Pearl Harbour, which brought the United States into the War, news was cabled to Europe that Bohr's prediction, as regards uranium 235, had been experimentally verified by the scientific workers at the University of Minnesota. By means of the mass-spectrograph principle, they had partly separated the two isotopes, of course only in absolutely infinitesimal quantity, and tests of their several reactions to bombardment by neutrons had been so promising that the commercial separation of uranium 235 had been started. That was the first intimation to the scientific world in general that the release of atomic energy for military purposes was no longer a chimera. But to anyone with any due appreciation of the Herculean task involved in the large scale separation of the isotopes, the likelihood of its being achieved in time to use in the War must have seemed very slight. Indeed, in the writer's view, it is still not a technological possibility, in the sense of being a practicable economic proposition as a source of power, as distinct from the provision of a super-explosive for objects in which its cost is not a total disqualification.

The Power Objective.

Before considering this development however, it is better to pursue to a certain stage the second process, aiming at the regulated and controlled release, which does not require this forbidding

* We have arranged with Dr. Soddy to publish his new book, *The Story of Atomic Energy*, in the form of a series of articles which are appearing at fortnightly intervals approximately. Dr. Soddy, however, retains the copyright, therefore no extract may be made from these articles without his permission.—Ed. E

separation, but, on the other hand, calls for relatively enormous quantities of uranium as the primary condition. At first it had been thought possible that, merely by bringing together sufficient uranium, its spontaneous fission might start. F. Perrin, one of the younger of the Paris theoretical physicists and the son of Jean Perrin, of Brownian-movement fame, had provisionally estimated the quantity necessary as a sphere of uranium oxide 9 ft. in radius, weighing 40 tons. But it is now known that, because of the loss of neutrons by resonance capture, producing U239 as already mentioned, no quantity, however great, would suffice. Hence arose the germ of the idea of what has since been, rather cavalierly, termed the "uranium pile," for it constitutes what is probably so far the high-water mark of human intelligence, ingenuity and achievement.

The Moderator.

To prevent this loss, the neutrons have to get out of the uranium producing them as soon as possible, and to be deprived of their initial velocity and kinetic energy before re-entering it as thermal neutrons, to effect the fission of the 235 isotope. This is the function of what is termed the "moderator." This, essentially, must be one of the lightest possible elements, the nuclei of which are nearest in mass to the neutron, whereby at each successive collision the latter is robbed of the largest possible proportion of its energy, and at the same time it must not be transmuted by it. In practice, so far, only two are available, deuterium and carbon. The first, in the form of heavy water, is much the superior for this purpose, though as yet too costly and time-consuming in manufacture for anything but experimental use. The latter possesses, in spite of the six-fold greater mass of its nucleus, the great merit of being obtainable in any quantity in the form of the artificial graphite manufactured in the electric furnace, and of sufficient freedom from impurity for the purpose, since almost everything else but carbon is volatilised away at these temperatures.

The Uranium Pile.

The uranium pile is an ordered special pattern, or three-dimensional lattice, of separate small units of uranium, in a matrix of the moderator. The distribution of the uranium relatively to the moderator is cunningly calculated, from all the available data concerning the properties of the neutrons and nuclei involved, to ensure the largest possible proportion of the neutrons, liberated by the uranium, returning to it after being robbed of their pristine energy. The losses due to unwanted transmutations are in this way minimised as far as possible. As regards controlling the process, if and when it starts to increase in speed, the difficulty has been all the other way, to reduce the unavoidable loss of neutrons to the point necessary for it to start. It is simplicity itself to introduce into the pile more or less of such elements as cadmium, already mentioned as avid neutron absorbers, and to regulate their quantity to the correct amount to maintain the process at any prearranged level after it has started. For this purpose rods of special boron steel are ordinarily used, which are drawn into or out of the pile as required.

As already stated, though most of the neutrons liberated by fission have sufficient energy to cause fission of the 238 isotope, relatively few do so. It is the loss, by resonance capture of the neutrons reduced to the intermediate energies, that is most important and which must be minimised by correct design of the lattice. While in the graphite moderator, the neutrons are estimated to travel about 1 in. between successive collisions with the light carbon nuclei of which it is made, and to make about 200 such collisions before they re-enter the uranium to produce fission in the 235 isotope.

According to the official United States publication, *Atomic Energy*, in which practically all that is known to the general public since Pearl Harbour, December 7, 1941, is contained, the first uranium pile to be constructed consisted of six tons of metallic uranium and an unspecified quantity of uranium oxide, presumably added for lack at the time of sufficient metal. This was built up into spherical form, with horizontal layers of blocks of graphite between similar layers of graphite blocks intermingled with blocks of uranium. The critical size, when the loss of neutrons balanced their production, was reached when only three-quarters finished and so the whole sphere was therefore never actually completed.

Built originally on the floor of the squash-court in the West Stands of Stagg Fields, in the grounds of the University of Chicago, it started operating on December 12, 1942, at the calculated initial power of one-half watt. After twelve days this was raised to 200 watts, but it was not considered safe to go higher, on account of the lethal rays generated, and it was subsequently removed to the Argonne laboratory outside the city. Here two others were also erected, for experimental study of neutrons, one in 1943 practically the same as the first, except that the simple cubic form by then had been correctly adjudged sufficient to give the critical requirement, and the other (1944) with heavy water as moderator, which enables the size to be greatly reduced. This last became self-sustaining when only three-fifths of the moderator had been added, so that some of the uranium could be removed and additional control rods had to be installed. By this time the manufacture of heavy water had been started in the United States and Canada, in the first from ordinary water by a simple, but costly, fractional distillation process, and in the second, by the physico-chemical process of catalytic exchange between electrolytic hydrogen and deuterium in water, which proved economical.

The Clinton and Hanford Installations.

Neither of the piles had cooling systems, and so were limited in output by their natural rate of dissipation of the heat generated. The first remained in constant action for two years without any major trouble, operating at a few kilowatts, but occasionally at much higher power for very short periods. From the experience with these experimental plants, "production" piles were built, the first as a "pilot" plant, at Clinton, Tennessee, and later others at Hanford on the west bank of the Columbia River, in the middle of the State of Washington, north of Pasco. Here five were designed, spaced several miles apart for safety, and three had been completed by the summer of 1945, one having then been in operation for a year. These were provided with water and air cooling systems which necessitated using much larger quantities of material and were designed to work at thousands of kilowatts. But little direct information has been released as to their performance, except for the first at Clinton, which by 1944 was working at over 1,800 kW. At Hanford, in an area comprising a thousand square miles, the first sod was turned in April, 1943. By 1944, a city of 60,000 people had sprung up in a region before of barren hills and sage-brush plains, containing only two small villages and a few farms. Now the city is again deserted, the operating personnel living in one of the two villages.

The Greatest Achievement in History.

The military objective prompting this vast and, save under the direst stress of necessity, perilously rapid expansion, from the half-watt stage to something rivalling the performance of the largest hydro-electric installations, was not energy: that merely went to waste, warming the Columbia River. But before considering the real objective it has been convenient to deal first with the development of the uranium pile for its own intrinsic interest and importance. For, in the writer's view, it marks the most god-like scientific achievement of the human brain in all recorded time. At the end of 1942, all the ingenious arsenal of high-voltage installations rivalling the lightning, marvellously accurate mass-spectrographs, cyclotrons weighing thousands of tons and costing hundreds of thousands of pounds, all the incredibly delicate devices counting and photographing the tracks of individual atoms of matter by which the quest, started by Rutherford in 1911 when he discovered the atomic nucleus, had been pursued all over the world, disappeared like the scaffolding of a building erected. Instead, appeared the correct assembly of a few tons of the element with the heaviest atom known, in juxtaposition with an element having one of the lightest. Lo! as the pile grows it starts of itself to generate energy on a scale over a million-fold the utmost last century achieved and, if not under human control, would give on earth an exhibition of incandescence paralleled only by that which is given by the sun and stars. It is terrifying to reflect into what sort of hands science has so prematurely delivered powers, which hardly more than four years ago, seemed still immeasurably beyond our grasp.

Tomic and Atomic Energy.

Now that atomic energy has been artificially set free in quantity, it is a simple contradiction in terms to speak of it after release as atomic energy. The term means the energy of the indivisible, and the scientific implication is that the energy that would be released if the indivisible could be divided. The negative of atomic would be an-atomic or not indivisible, a word already in use, however, for example, as anatomical, meaning dividing up. Hence the writer uses the positive term tomic, instead of the negative term atomic, for the energy after it has been released by the division of the atom, though it is still quite correct to use the term atomic energy to signify the energy latent in the atom, before it is released by its division.

The Conditions for Tomic Detonation.

The main difference between the problem, solved by the uranium pile just described, and that of making uranium a true tomic explosive is one of time. No doubt, if the uranium pile were not controlled, it would generate a terrific explosion. But only a very insignificant proportion of the energy of the uranium would suffice for that. What would probably happen would be that, exactly as in any chemical explosion, the energy released would gasify the material at the place it started, but, in this case, blowing the rest to the four winds completely unchanged. For not the rise of temperature but the concentration of neutrons causes this type of explosion. The necessary neutrons, instead of being concentrated in the uranium, would instantly escape, bringing the detonation to a stop, almost as soon as it started. This condition requires the true initial detonator, the 235 isotope, to be concentrated from the 238, which for this purpose is so much diluting matter. At any rate, though over 99 per cent. of the whole uranium, its contribution to the starting effect is relatively negligible. The condition also rules out the thermal neutrons as the detonating agent, as their rate of propagation through the material is the same as that of an ordinary chemical explosion, and only the fast neutrons, travelling at an appreciable fraction of the speed of light, can serve this purpose. Hence the problem is quite different from that of the self-sustaining uranium pile. But little has been divulged either as to details of construction of the tomic bomb, or of the probable actual course of the explosive type of atomic fission, beyond these two essential conditions for it to be propagated with sufficient speed for an appreciable proportion of the fissionable material to be exploded before its dissipation brings the process to an end. Practically nothing is revealed so far even as to the order of magnitude of the critical quantity above which detonation occurs. The original theoretical estimate was somewhere between one and a hundred kilograms of U 235.

Detonation happens, of course, so soon as the neutrons produced by fission exceed those absorbed by fission, plus all losses due to escape of neutrons from the surface and those absorbed in causing transmutations other than fission. Each kilogram of uranium element actually fissioned releases energy similar to that liberated in the explosion of 20,000 tons of tri-nitro-toluene, or similar high-explosive. The general impression seems to be that, so far, not one per cent. of the energy of the whole uranium, as it occurs in nature, has yet been explosively released, and that, for practical purposes, the 238 isotope present in uranium, enriched in the 235 isotope, may be regarded as a diluent rather than contributor to the destructive effect. In any case, since a tomic detonation cannot be studied under laboratory conditions at all, any evidence as to this, it would appear, must be only very indirect and inferential.

THE TOMIC BOMB.

But, broadly, the problem seems to have been solved by dividing the charge into two separated parts, in each of which the volume and surface conditions ensure an escape of neutrons in excess of production, and then, as suddenly as possible, bringing them together, so that the new volume and surface considerations of the assembled charge ensure the reverse, and instant detonation ensues. This, for any given concentration of the initially fissionable constituent, limits the total charge of the bomb to a definite quantity which cannot be far departed from. The whole technical difficulty being to bring the two parts together in a hardly measurable time, from start to finish, it would seem inevitable that any attempt to use more than two parts must fail for lack of sufficiently exact synchronisation, though this is only surmise. Also, as a military weapon, a tomic bullet would be much better than a tomic bomb probably, and there certainly seems no call to multiply the power of the latter, but rather the opposite, that is to subdivide it.

As to how the double charge is assembled, we are given the impression that the one part is fired at the other, inside the bomb, by some sort of gun, or other equivalent device. There is no information as to whether a source of fast neutrons, such as the radium-beryllium tube, has to be incorporated to ensure instant detonation on assembly; for the uranium pile none is necessary. The process here is regarded as being initiated either by a cosmical-ray neutron, or what is termed a "stray neutron," resulting either from a spontaneous fission of a uranium atom, or by the action of its α-rays upon one of the other elements present. The only other point that calls for mention is that, as in ordinary explosions, the tamping of the bomb, as by surrounding it with the densest possible material, which by its inertia delays the dissipation of its contents after detonation as long as possible, plays an important role in the conditions that help to enable the full force of the explosive to be generated.

THE SEPARATION OF THE URANIUM ISOTOPES.

The actual methods attempted to effect sufficient enrichment of the 235 isotope of uranium were all purely physical, those previously worked out for the physico-chemical separation of the ligher isotopes, several of which, besides deuterium, had been already, by 1940, wholly or partly separated, being ruled out by the high atomic weights and small difference between them, according to the quantum considerations dealt with in Part X. Three methods were mainly employed, diffusion of the vapour of a uranium compound through porous septa, thermal diffusion of the same in liquid form, and methods adapted from the principle of the mass-spectrograph depending on the variation with mass of the deflection of individual positive ions in powerful magnetic fields. Actually, the first, probably, was used mainly for a preliminary enrichment, the second, less extensively developed, for an intermediary stage, the final separations being done by the last. It is a gigantic combined technolgical operation, with no parallel in the whole history of industry, and is completely outside ordinary commercial present possibility, at least to initiate, and probably also afterwards merely for providing a new source of power.

The only compound before known suitable for the diffusion process, is uranium hexafluoride, UF_6, a solid, vaporising to a gas at 56 deg. C., and atmospheric pressure. It is eligible by reason of fluorine consisting of a single isotope, but chemically very undesirable on account of its high reactivity and corroding properties. Whether these difficulties were overcome, or a better compound found, is not made known. The relative proportion of the two isotopes is only changed by less than one-half per cent. by one diffusion, and thousands of successive diffusions in a properly arranged cycle of operations would be required to effect anything approaching complete separation. The consumption of power is colossal, and the production plant, installed at Clinton to operate the process, required the provision of a larger steam generating plant than ever before built. There are grounds for thinking this consumption of power in separating isotopes is theoretically unavoidable. A Russian mathematical physicist has estimated it to be comparable with the energy of fission of the 235 uranium isotope separated. Even to separate air into its constituents, by physical methods of diffusion and the like, theoretitally calls for a not inconsiderable amount of energy to be expended. Since no technological process before had depended on diffusion, the whole practice had to be threshed out from the start, and that too for about the most difficult possible case.

The second process of liquid thermal diffusion had first been devised for isotopic separation, following a very successful similar process for gases, and, though equally extravagant in power requirements for any great degree of enrichment, was successfully operated, probably mainly as an adjunct to the other two processes, at Clinton on the production scale. Both immobilise enormous quantities of uranium permanently in the plant, in the working cycles, which delays the completion of the process a considerable time.

THE CALUTRON.

The third method is the exact opposite in almost every respect. It gives a relatively high enrichment in a single stage but deals with only very minute quantities in a single unit. At the start it required months of work to collect one milligram, but for more than a year the enriched uranium, urgently required for the necessary experimental data to be worked out, was supplied by this means. The first apparatus was built from a former mass-spectrograph magnet of 37 in. diameter poles, and so it was called the "calutron", an abbreviation of California University cyclotron. Later, the magnet of the Berkeley cyclotron in course of construction, weighing 5,000 tons, with 184 in. diameter pole pieces, was impounded for experimental work in this field. The yields were gradually increased very considerably, but to what extent is not stated. The production plant, also built at Clinton, is probably the most bizarre ever worked, consisting of a sufficient number of these laboratory units, each involving a colossal electromagnet, giving the required output which the problem demanded, by sheer multiplication of single units. It is nothing less than the application of a method, originally handling atoms almost as individuals, to mass production, and there are more atoms in the smallest visible speck of uranium than there are people in the whole world. Even so, one-half of the actual production side of the process, by which finally enough concentrated fissionable material to make three atomic bombs was collected, remains to be told. For, as already said, similar intensive work had been going on in connection with the self-sustaining uranium pile, as it offered an alternative method of achieving the same object.

THE TRANS-URANIC ELEMENTS.

This brings us back to the real trans-uranic elements, the first of which, No. 93, is the product, by β-ray change (half-period 23 minutes), of the 239 isotope of uranium produced in the, so far as yet pursued, unwanted resonance capture of neutrons of intermediate energy by the 238 isotope. This product element No. 93, in turn, emits another β-ray in a change of half-period 2·3 days, and therefore turns into No. 94. These two new elements, Nos. 93 and 94, beyond the Periodic Table of the Natural Elements, have been aptly named Neptunium and Plutonium, respectively. It was anticipated, by analogy with natural radioactivity, that plutonium, in turn, would emit an α-ray and so change into the 235 isotope of uranium. This has since been established, but the change is so slow, the half-period being first estimated as at least a million years—more recently 24,000 years—that plutonium is essentially for this purpose as stable an element as uranium.

However, it was also inferred that, like U 235, plutonium might suffer fission by slow neutrons, and, if so, being a different element from uranium, and therefore chemically separable from it, the fantastically heroic physical separation of the two uraniums by diffusion and the calutron first gone into, would in this way be completely avoided. All of this has turned out to be true, though it proved, in some respects, an exchange of the deep sea for the devil, and in others, in the engineering of the work, was to assume an even more fantastic character.

PLUTONIUM.

The cyclotrons in the United States were immediately turned on to produce plutonium artificially by the bombardment of uranium, first with deuterons and later with neutrons. These produce two different isotopes, but that makes no difference so far as the chemistry of plutonium is concerned. By the end of 1942, half-a-milligram had been so collected, which proved sufficient for radio-micro-chemists to determine its main chemical character and to suggest, in outline, methods for its large-scale separation from the uranium producing it in the pile. We must leave for the present the purely scientific advances, of intense interest and importance, that have resulted from this extension of the Periodic Table of elements—now pushed two places still farther to No. 95, Americum, and No. 96, Curium—in order to have done with the war-work that culminated in the tomic bomb.

The great battery of "production" piles at Hanford were to produce plutonium, not power. The target aimed at is not revealed beyond that it was very large, and involved the separation from each plant-unit of some grams per day of plutonium from some tons of uranium, the ton being a million grams. But its scale may be compared with the power plant of a large hydro-electric station, as in the production of each gram per day of plutonium, heat energy is released at the rate of the equivalent of one thousand kilowatts. The cooling water required at the Hanford plant, to get rid of this, is stated to be comparable to the water-supply of a fair-sized city.

The fantastic feature of this second half of the production work was that all this vast enterprise was planned and started when only the first pile to be made, working at 200 watts, had been actually brought into operation. The lethal rays from the pile quite preclude any maintenance work upon it once it has begun to operate. It has to be entirely surrounded by heavy concrete and steel shields, as far as possible air-tight against the exit of neutrons and radioactive gases, and the process of feeding in and discharging the uranium passing through must be conducted from the outside entirely by remote control. The uranium metal was cast into the form of cylindrical "slugs," and "canned" in an air-tight aluminium casing to protect it from corrosion by the cooling water. These slugs were pushed in at one end, through horizontal cylindrical channels perforating the cubical pile, and out at the other for the separation process, according to a regular time-table.

But the task of designing the separating plant sounds even more of an engineering nightmare. It is housed in a horizontal channel, or canyon, two-thirds buried in the ground, divided into a longitudinal array of separate cells, and is 100 ft. long. The operations of dissolving the uranium and disposing safely of the intensely radioactive gases—isotopes of iodine, xenon and krypton—which are liberated, separating the plutonium from the million-fold greater quantity of uranium, and then from the intensely active and dangerous fission products, comprising some 20 different elements, to the point at which it could be safely handled, had all to be done under the same limitations, by remote control from without. To crown all, this complex operation had to be provided with production plant before it was rightly understood what methods of chemical separation would ultimately be adopted, and it was done from a knowledge of the properties of plutonium derived from a world-stock at the time invisible to the naked eye. Yet we learn the whole project was a complete success from the start. Truly fortune favoured the brave!

The "pilot" plant, put up at Clinton simultaneously, came into operation at the beginning of 1944, and had delivered several grams of plutonium by the end of February, the metal going through at the rate of one ton in three days, and the efficiency of the recovery process had been got up to 80 or 90 per cent.

THE POISONING OF THE URANIUM PILE.

However, one unexpected effect came to light in the operation of the production piles which seems to make this process vastly more laborious and less

practical than it would otherwise have been, and also seems imperfectly accounted for. It is referred to by the technical name of "poisoning," presumably from the use of this term in chemistry as meaning the destruction, or loss, of catalytic activity through causes ascribed to contamination of the catalyst with traces of substances in the materials treated, or produced from them, acting as "poisons," but not really understood. Here it is ascribed to the accumulation of the products of the reaction, the plutonium and the fission products, that appear to be quite abnormally avid of neutrons, the accumulation of which products tends continuously to reduce the margin available for sustaining the pile in action. We learn from the official story that an effect of this kind nearly prevented the Hanford piles operating "as will later appear," but nothing further is included as to this.

It seems to account for the very short time, probably a few days only, the uranium remains in the pile, necessitating the whole elaborate separation process to be gone through for each relatively infinitesimal proportion of plutonium. In so far as the neutrons are lost by plutonium absorption, presumably fresh neutrons are produced just as with the uranium 235, helping to sustain the pile, though resulting in loss of plutonium. This effect, in spite of the fact that otherwise plutonium is a stable product, would, if large enough, result first in an equilibrium condition in which the amount of plutonium ceases to increase and then the plutonium, if not removed, would begin to decrease. As regards the loss by fission-product absorption, the effect, should enough such products accumulate, is to stop the pile altogether. This is the main reason why it still remains very doubtful whether this alternative method, in contrast to the physical separation of the 235 uranium, does or can render available the 99·3 per cent. proportion of the atomic energy of the 238 isotope, as was thought would be one of its advantages, when it was originally proposed, and is the most important lacuna in adjudging the probable future of atomic energy in making history.

The United States had Only Three Tomic Bombs.

The sequel to this war-effort needs no re-telling in this story. It must suffice here to say that, by the middle of July, 1945, enough fissionable explosive had been accumulated for a secret trial test at Los Alamos, New Mexico, where the laboratories in connection with the final stages of research into the construction of the tomic bomb had been located. This was followed, on August 6, by the destruction of Hiroshima, by the first, and later in the week of much of Nagasaki by the second tomic bomb, together with a large part of their inhabitants, either by the direct flash or shock, or the delayed action of the lethal rays, causing death by anæmia and similar effects. It seems to be generally believed in the United States that the first bomb contained the 235 uranium isotope and the second plutonium, though there does not appear to be any official disclosure as to this. But quite recently, January, 1947, the then United States Secretary of War, Mr. Henry Stimson, revealed that these three bombs were the only ones then ready, thus confirming what those aware of the extraordinary difficulty of separating the uranium isotopes must all along have suspected.

The New Light on the Periodic Law.

Without going too deeply into its numerous complexities, it is possible to describe broadly the most important scientific conclusion that has now developed from the extension of the Periodic Table of the chemical elements, beyond the natural end at uranium, to the transuranic elements. The extension happens to be of particular interest to the writer, who has always thought the natural sequence already extended three places too far for the previous course of evolution—that is, up to radium, No. 88, and actinium, No. 89—to continue further. For, in the preceding period at the place No. 57, lanthanum, corresponding to actinium, No. 89, there begins the series of fifteen (one place being vacant) successive elements, known as the rare-earth elements, all of essentially similar chemical character, trivalent in their main compound, and the nearest approach to chemical inseparability before the discovery of isotopes.

It now appears that in this final period of the Periodic Table, the same sort of thing repeats itself, so far as yet explored, but instead of beginning at No. 89, actinium, it begins three places farther on at No. 92, uranium, the subsequent elements, Nos. 93-96, Neptunium, Plutonium, Americum and Curium, being close copies of uranium, though, so far as yet explored, less so than for the rare-earths. These elements form many series of salts of different valency, but the tendency seems to be to revert to the final form of trivalency as the series proceeds, so that the last yet reached, Curium, seems to give only trivalent stable salts.

As one of the most important consequences, both scientific and practical, of the new method of mass-generation of neutrons by the uranium pile, is this possibility of extending the range of elements beyond the natural; this further development may well ultimately prove to be also of practical importance. The chemist primarily responsible for disclosing this is G. T. Seaborg, now at Chicago University. Apologies must here be tendered to most of the, no doubt, large number of actual discoverers who contributed to the secret team-work described in this Part for the writer's inability to mention them by name, as for the most part they remain unknown, except to their immediate colleagues in the work.

In addition to plutonium it is now known that a stable isotope of neptunium, is produced in smaller quantity in the uranium pile. The other two elements result in the bombardment of uranium with 40 M.e.v. artificial α-particles generated by the largest Berkeley cyclotron—the magnet of which has 60-in. pole-pieces and weighs 220 tons. But Seaborg anticipates that, when the large one with 180-in. poles, the completion of which was interrupted by the war, is got working, and by which it is now confidently hoped to generate particles up to 400 M.e.v., an entirely new chapter may be opened up in the accomplishment of atomic fission, even of the lighter elements, and in the artificial production of entirely new elements.

Neptunium.

In the uranium pile, in addition to the radioactive uranium isotope 239, changing speedily into plutonium, through neptunium, both having this mass number, another radioactive isotope of uranium, of mass number 237, is also formed, by a type of change fairly frequent with the heavier elements by neutrons of sufficient energy. This involves the net loss, instead of the gain, of one neutron by the nucleus bombarded. The neptunium 237, resulting from this uranium isotope by a fairly rapid β-ray change, is essentially a stable element, with a half-life of over two million years, and it emits α-rays. Hence neptunium, as well as plutonium, is now producible in weighable quantity, but not so far the other two, Americum and Curium.

This new long-lived isotope of neptunium, $^{237}_{93}Np$, in modern symbolism, and its parent, $^{237}_{92}U$, represent the start of a new type of radioactive disintegration series, previously unknown, called the $4n + 1$ series, this with n integral, giving the mass numbers of the successive members. As in radioactive changes, only α- and β-particles are expelled, the former reducing the mass number by 4 and the latter leaving it unaltered, this form necessarily represents all the members of any such series. Of the previously known series, the thorium series is the $4n$ series, the uranium series $4n + 2$ and the actinium series $4n + 3$, and it had long been a matter of theoretical interest that no $4n + 1$ series should be known. According to a chart of these four disintegration series prepared by Professor F. Paneth, and exhibited at the recent Exhibition (1947) at the Science Museum, South Kensington, in connection with the Centenary Celebrations of the Chemical Society, from $^{237}_{93}Np$, after a hiatus comprising three α-changes and one β-change, corresponding to three still unknown members, the rest of this artificial $4n + 1$ series produced in the uranium pile is now known. It comprises eight members, the last being common stable bismuth, $^{209}_{83}Bi$, and the others isotopes of the elements from radium to lead. But this new series passes through the vacant places, Atomic Nos. 87 and 85, missed by all the other three, to which the names Francium and Astatine have been given. His $4n + 1$ series is reproduced below, the symbols being put in square brackets to indicate that they are new isotopes of the known elements having these symbols, Fr and At being used as symbols for Nos. 87 and 85, and the periods of average life being shown below.

$$^{237}_{92}[U]\ (10\ d.) \xrightarrow{\beta} {}^{237}_{93}Np\ (3{\cdot}23 \times 10^{6}\ y.) \xrightarrow{\alpha} \ldots\ {}^{225}_{88}[Ra]\ (20\ d.) \xrightarrow{\beta}$$

$$^{225}_{89}[Ac]\ (14{\cdot}5\ d.) \xrightarrow{\alpha} {}^{221}_{87}Fr\ (7\ m.) \xrightarrow{\alpha} {}^{217}_{85}At\ (3 \times 10^{-2}\ s.) \xrightarrow{\alpha} {}^{213}_{83}[Bi]\ (66\ m.)$$

$$\xrightarrow{\beta} {}^{213}_{84}[Po]\ (10^{-5}\ s.) \xrightarrow{\alpha} {}^{209}_{82}[Pb]\ (4{\cdot}7\ w.) \xrightarrow{\beta} {}^{209}_{83}Bi.$$

No doubt some of the details of this intensely interesting new artificial $4n + 1$ disintegration series have been filled in by inference rather than as yet established by direct experiment. But it brings to a fitting close the amazing series of fundamental discoveries in the physical sciences, enlarging almost out of recognition our knowledge of the atom, which began, so unheralded by any hint of what so soon it was to become, when Henri Becquerel discovered in 1896 that certain crystals of uranium salts, the fluorescence of which his father and grandfather had studied, fogged the photographic plate, wrapped in a light-tight envelope, through thin plates of metal, even in absolute darkness and when they had never been exposed to light at all.

THE STORY OF ATOMIC ENERGY: ERRATUM.—We regret that the block of Fig. 88, on page 361, *ante*, was accidentally inverted. Of itself, this is of no consequence, but in the reference to this illustration, which appears near the bottom of the middle column on page 362, "below" should be read instead of "above" in line 6 from the bottom of the column; and in line 5 from the bottom, for "lower" surface read "upper" surface.

CONSTRUCTION OF PROPELLER TEST BEDS AT HATFIELD: ADDENDUM.—In the article on the construction of the propeller test beds at Hatfield for the de Havilland Aircraft Company, Limited, on page 332, *ante*, the name of the consulting engineer for the reinforced-concrete work was given as Mr. H. Iorys Hughes, M.Eng., M.I.C.E., M.I.Struct.E. We have been informed, however, that Mr. Hughes' partner, Mr. A. B. Newby, A.M.I.C.E., was in charge of this work.

REFRESHER COURSE IN IRON METALLURGY.—The first post-war refresher course held by the British Cast Iron Research Association took place at Ashorne Hill, near Leamington Spa, by courtesy of the British Iron and Steel Federation, from April 14 to 17. More than 200 representatives of member firms, and also students of the National Foundry College and members of the Association's staff, attended the course. Upwards of 20 lectures were delivered by the staff of the Association and by Mr. J. W. Gardom, Mr. L. W. Bolton, and Mr. A. E. Probst.

SOUTH-WEST ESSEX TECHNICAL COLLEGE.—The list of examination successes obtained during the 1946-47 session, given in the ninth annual report of the South-West Essex Technical College and School of Art, Forest-road, Walthamstow, London, E.17, indicates the wide range of the work carried on in the College. Of the London University examination successes, 13 B.Sc. degrees were obtained, three of them B.Sc. (Eng.) and two B.Sc. Special (Physics). In addition, Mr. R. A. Weil obtained the M.Sc. degree in physics and Mr. D. J. Price and Mr. J. H. Wilkinson the Ph.D. degree. In addition, and mentioning only engineering examination successes, 42 passes, including 14 distinctions, were obtained by candidates for Higher National Certificates and 36 passes, including nine distinctions, by candidates for Ordinary National Certificates in mechanical, electrical and production engineering. During the 1946-47 session, 7,760 individual students attended the College and worked 1,152,529 student hours, as compared with 5,968 students and 923,487 student hours in the 1945-46 session. The report adds that the volume of scientific and technological research carried out at the College is steadily increasing. During the session referred to, there were ten full-time and nine part-time investigators apart from members of the staff, engaged in research work.

LABOUR NOTES.

DISCUSSING the Government's Economic Survey for 1948, the writer of the editorial notes in the April issue of *Man and Metal*, the journal of the Iron and Steel Trades Confederation, expresses the opinion that steel is destined to play what may well be a decisive part in the plans. "Steel," he says, "is the hub around which the whole of our productive effort revolves, and upon which everything depends. Despite the record outputs of recent months, it is feared that supplies of steel, due chiefly to lack of imports and the need to export are likely to be the principal limiting factor throughout a large part of British industry during 1948. Levels of output in the engineering industry will be dictated very largely by steel supplies. The fulfilment of export targets, the expansion of agriculture, coal-mining, oil production and refining, and the provision of new industrial equipment and material for the railways, will eat up every ounce of steel available, and will still leave the steel consuming industries short of their full requirements."

"The steel industry is given," he writes, "an output target of 14,000,000 ingot tons, and although it has recently been demonstrated that this is within the capacity of the industry, its attainment will depend largely on an adequate supply of fuel and raw materials and freedom from transport difficulties. Although it is not regarded as completely adequate, 14,000,000 tons is the most that the Government expects the industry to produce under present circumstances, but this output can quite easily be placed in jeopardy if supplies of scrap, pig-iron, or coke fail to come up to expectations."

"The Government," the author of the notes continues, "will exercise the greatest possible economy in the uses to which steel is put, and steps have been taken to ensure that the machinery for its allocation and distribution works with smoothness and efficiency. Extensive plans have been made and are being put into execution for the expansion and modernisation of the industry but it will be another two or three years before any significant results are visible. In the meantime, in order to achieve the Government's target figure, the utmost use must be made of available plant capacity. Of one thing we are quite certain; if the target figure is not reached, it will not be the fault of the work-people in the industry."

Further on in his notes, he refers to the recent conference of trade-union executives which considered the Government's suggestion on the subject of wages, prices, and profits. "The situation with which the conference was confronted was," he writes, "unprecedented in trade-union history, and, to meet it, required all the courage, commonsense and experience that the Movement could muster. It was an extremely difficult decision that the conference was asked to take. For the T.U.C. to advise unions to exercise restraint in the pressing of wage claims appeared to be contrary to all previous trade-union practice and policy."

"We are, however, living in 1948, not 1920," he goes on, "and for anyone to suggest that the only function of the trade unions is to press for higher wages irrespective of the consequences of this on the grave economic situation the nation finds itself in to-day, is a flat repudiation of our responsibility and an abdication of our claim to that position of influence and authority which has been fully accepted and recognised by the nation at large."

Writing in the latest *Monthly Trade Report* of the United Patternmakers' Association, Mr. Beard, the general secretary, says: "The day has passed when the people of a democratic nation can leave the management of its affairs to statesmen "born" to the job or to those who enter management solely from the top. In a true democracy, all should realise his or her obligation to the community as a whole. This is not completely appreciated as it should be, for, even as I write these lines, busmen have gone on unofficial strike and put their fellow-workers to great inconvenience. The reason appears to be that a small minority do not agree with the decision of a majority of their own elected representatives to accept an increase in wages of 7*s.* 6*d.* a week. There are, one can agree, rights of minorities, but actions of this kind are the very negative of democracy, as I understand it, and unfortunately, this is not an isolated case by any means, for, time and again, strikes occur after settlements have been effected through agreed machinery . . . The time is approaching when we will require a new conception of trade unionism based upon a full realisation of the responsibility for the maintenance of comparative full employment and a good standard of living."

Representatives of the National Association of Unions in the Textile Trade agreed last week to accept the wage increases offered by the employers. Under the settlement terms—which have effect as from April 3—the wages of scheduled male employees are increased from 84*s.* to 90*s.* 4*d.* a week, and those of unscheduled employees from 82*s.* to 90*s.* Women employees receive an increase of about 5*s.*, making their minimum 60*s.* About 180,000 operatives are affected in the West Riding of Yorkshire, and parts of Scotland and Lancashire.

The Ministry of Labour and National Service states that the official index of retail prices for March was 106—the same figure as for February. This index, it will be recalled, has taken the place of the old cost-of-living index and measures changes in retail prices since June last year, the prices then ruling being reckoned as 100.

Official figures relating to the coal-mining industry indicate that in the week which ended on April 17, absenteeism among coal-face miners was 12·93 per cent., compared with 15·8 per cent. in the previous week. Voluntary absentees accounted for 7·2 per cent., compared with 9·31 per cent., and involuntary absentees for 5·73 per cent., compared with 6·49 per cent. Absenteeism among all miners fell to 10·61 per cent. from 12·08 per cent., and was made up of 5·63 per cent. voluntary, compared with 5·79 per cent., and involuntary absenteeism to 4·98 per cent. from 5·29 per cent. The deep-mined tonnage lost in the week which ended on April 17 through disputes, accidents, and other causes was 64,300, compared with 34,500 in the previous week.

In the agenda for the forthcoming annual conference of the Labour Party, there are 43 resolutions and amendments dealing directly or indirectly with the subjects of wages, prices and profits. Following the Transport and General Workers' expression of "grave concern" at the effects of unchecked profits on the standard of living, and a plea by them to the Government to curb excess profits, there are amendments in similar terms by other affiliated organisations, chiefly local labour parties.

A resolution which the Weavers' Amalgamation has sent in for discussion at next month's annual conference of the United Textile Factory Workers' Association, calls on the Government to limit profits; to act upon the proposals of the Committee of Investigation into textile machinery; and to speed-up re-equipment generally. A resolution by the Spinners' Amalgamation urges that payment for the two and a half hours' overtime now being worked in response to the Government's appeal should be exempt from income tax.

The claims of the shipbuilding unions belonging to the Confederation of Shipbuilding and Engineering Unions for substantial increases of wages were discussed at a conference in London on Wednesday last week, with the Shipbuilding Employers' Federation. The demands are for a minimum wage of 5*l.* 19*s.* a week for craftsmen and one of 5*l.* a week for unskilled workers. The shipbuilding and the ship-repairing industries are both affected. The application was supported by Sir John W. Stephenson, the chairman of the Confederation's shipbuilding group, and further consideration of the matter was adjourned in order to enable the employers' representatives to consult their local associations.

What eventually the outcome will be of the discussions which are in progress between the Crisis Committee of the Trades Union Congress General Council and the Chancellor of the Exchequer, is difficult to foretell with any degree of accuracy. The position of Sir Stafford Cripps and his colleagues in the Cabinet is clear enough; it is stated more or less in detail in the White Papers that have been issued. It is hoped that while the economic crisis persists, the unions will exercise restraint in applications for wage increases, and in order to induce them to hold their hands, the Government undertook to deal with prices and profits. At the moment, individual affiliated unions are showing little inclination to slow down or postpone their applications for wage increases while, on the other hand, the General Council, through its Crisis Committee, are pressing the Chancellor for more drastic treatment of prices and profits than has, so far, been done in the Budget or otherwise.

It is stated that at one of the conferences with members of the Crisis Committee, Sir Stafford Cripps declared that if profits and prices were not reduced voluntarily, the Government would enforce reductions. Whether they will do so, and how they will endeavour to fulfil the Chancellor's promise time must be left to tell but, obviously, if legislation is to be used to discipline employers, it may also be used to discipline the trade unions and their members.

THE ROYAL NAVY AND NUCLEAR POWER.*

By R. J. DANIEL, R.C.N.C.

THE most probable method of delivery of atomic missiles, aimed at a ship or squadron, will be by air, either as a bomb, guided or otherwise from a parent aircraft, or as the warhead on a guided missile. Further, in addition to choosing the moment and method of delivery, the enemy is also able to select where he desires the bomb to detonate, either in the air, on contact, or below the surface of the sea, at a depth which can, conceivably, be set while the bomb is falling. The atomic-headed guided missile is unlikely to be used against ships except in narrow waters until one protagonist has enough fissile material to render the possible loss of several weapons acceptable; also, in view of its vast power, the delivery of the bomb as a contact weapon is unlikely. The two most likely positions of detonation are the air and underwater bursts. Attack by atomic weapons of a more orthodox ship-borne character is considered unlikely.

The "Nagasaki" type of atomic bomb has been reported to have a power equivalent to 20,000 tons of T.N.T. This means that the detonation of an atomic bomb produces an air shock-wave equivalent to the shock wave that the detonation of 20,000 tons of T.N.T. would be expected to produce. This is necessarily approximate; for example, the bomb is practically a point source, while 20,000 tons of T.N.T. would be a sphere 100 ft. in diameter, and clearly the rate of propagation of the detonation through uranium or plutonium is vastly different from the rate in T.N.T.

An air-burst atomic bomb produces light, heat, air blast, and radioactivity (gamma rays and neutrons). The intense radiation will cause permanent or temporary blindness to exposed personnel; personnel within a mile of the burst and facing the bomb would probably be permanently blinded, while those facing away from the detonation would probably be blinded for a considerable period. The tremendous heat generated by the bomb is well known and its damaging effect on unprotected personnel can be imagined. Further, this heat pulse can ignite paints, cordage, textiles, and, of course, inflammables exposed to it on the ships, causing fires.

In free space, the air blast would spread as a spherical wave front, but when the bomb is detonated near to a surface the lower part is modified and a well-defined Mach formation occurs, speeding over the surface with, for the most part, the speed of sound. This air blast is of truly formidable magnitude; its order can be very approximately judged by scaling the pressure and duration results for a 1,000-lb. bare charge up to a 40,000,000-lb. charge giving a side-on pressure of about 10 lb. per square inch with a duration of positive pulse of nearly 1 second at 1,000 yards. Clearly, forces of this magnitude are going to cause death and injury to exposed personnel, varying from damaged lungs, and injuries from being forced violently against the ship's structure (or blown over the side), to perforated ear drums, as well as serious damage to the ship's structure and equipment. Fig. 1, opposite, shows the air-burst atomic-bomb explosion at Bikini. The pressure wave can be seen round the edge of the illustration.

The light, heat, and blast are effects which arise from the detonation of any explosive, but in addition, and really quite incidentally to its main function of liberating a colossal amount of energy for the smallest possible detonating medium, the fission produces an intense radiation in the form of gamma rays and neutrons, and a mass of radioactive fission products. The resulting fission products are initially in the ball of fire and rise with it, giving rise to the familiar mushroom-shaped cloud. The height to which the mushroom rises depends upon the existing meteorological conditions, but the cloud will drift away downwind (and this can be in different directions at various levels), depositing radioactive fission products as it goes.

The degree of damage and general phenomena resulting from the explosion of an atomic bomb under water will vary tremendously with the depth of detonation and the depth of water in which it occurs. It is probable that, if detonated at a depth of many hundreds of feet in very deep water, the resulting bubble phenomena would be similar to that from an orthodox explosive charge, expanding to maximum diameter after producing the first underwater shock wave, contracting to its first minimum to give a second positive pressure pulse, and then expanding again, and so on; all the while rising, finally to vent the fission products and steam in a plume on breaking surface. When detonated at a shallower depth, which is a more likely tactical use against a ship or fleet at sea, it is probable that the bubble would vent before reaching its first maximum, producing a plume of majestic proportions, similar to that seen after shot

* Paper presented at the Spring Meeting of the Institution of Naval Architects, held in London, March 17 to 19, 1948. Abridged.

ATOMIC BOMBS AT BIKINI.

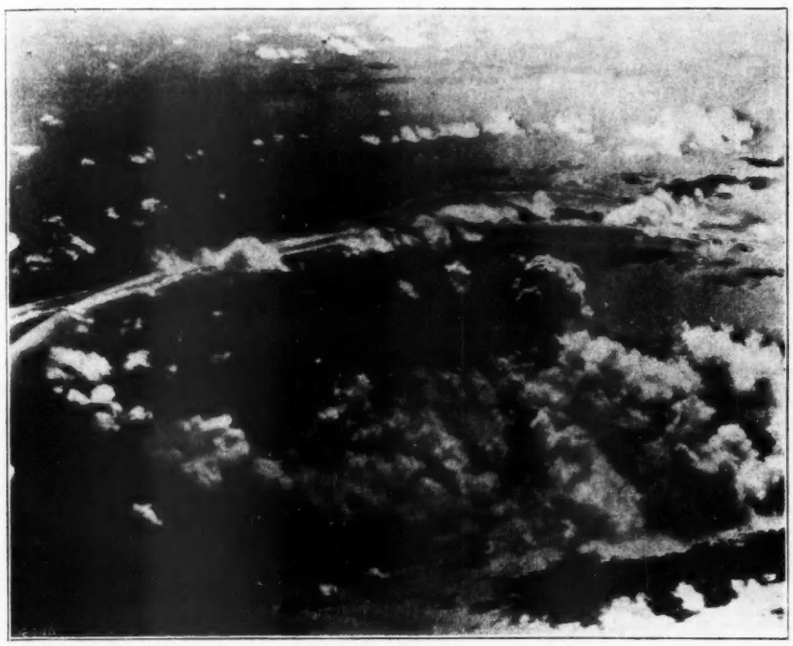


FIG. 1. AIR-BURST ATOMIC-BOMB EXPLOSION.

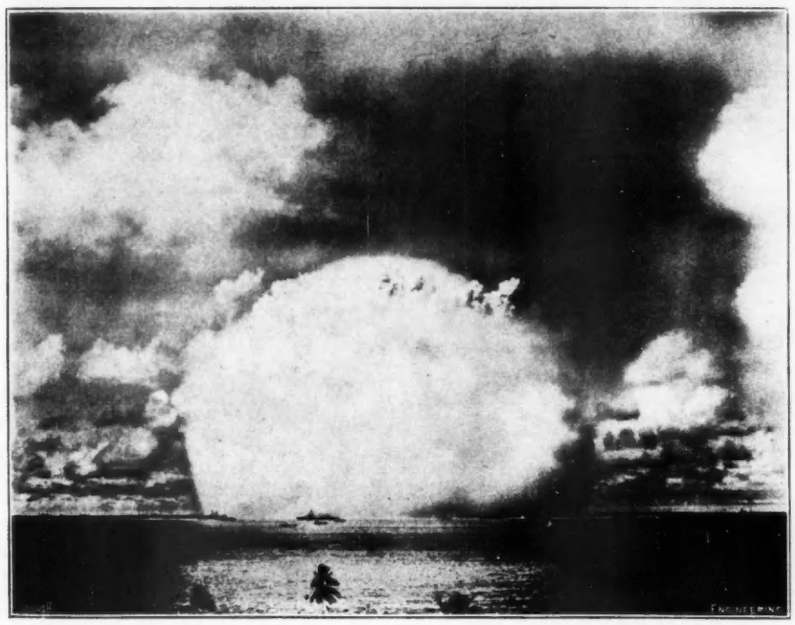


FIG. 2. FOG CLOUD IMMEDIATELY AFTER UNDERWATER EXPLOSION.

"Baker" at Bikini, illustrated in Figs. 2 to 4, on this page and on page 430. (The water column in Fig. 3 was about 2,000 ft. in diameter; the vertical dark patch in it is thought to be the U.S. battleship Arkansas.)

The principal phenomena resulting from an underwater detonation would be underwater shock wave, air blast after the bubble breaks surface, waves, and radioactive contamination of the target area. Due to the absorption by the water, the effects of heat and the initial radiation, both gamma ray and neutron bombardment, can be discounted save for extremely shallow detonations. Similarly, the light flash will be relatively unimportant, save for personnel in the vicinity of very shallow bursts. The underwater shock component of the total damaging effect will clearly increase in its relative effectiveness as the depth of detonation increases, at least until depths of several thousand feet are reached. From these extreme depths at which the bubble breaks up before reaching the surface and the fission products diffuse into the water, the total damaging effect—which may be negligible—is due to the underwater pressure pulse

In an infinite depth of water, the pressure recorded at any point would be that due to a steep-fronted spherical compression wave moving along a straight line between the bomb and the point, followed by the arrival of a tension wave reflected from the surface, this second wave eating into the positive pressure wave still existing and reducing it to zero—the surface cut-off. The presence of the sea bed does not alter the fundamental nature of this assertion, but introduces complications; for example, there will be a reflected compressive pulse from the bottom (its strength depending on the nature of the bottom) and a reflection in the bottom of the first tension reflection in the surface, and so on. These impulses arrive at any point in the fluid in succession, following the initial wave. There is one impulse that can, in some cases, arrive before the direct pulse—this is the transmitted wave which passes through the sea bed and upper strata, is reflected at a dense interface, such as a change from chalk to granite, and passes back into the water and to the point of measurement.

From consideration of the energy released by the bomb, the resulting main underwater pressure pulse must clearly be of high pressure and long duration, the latter governed by the arrival of the surface-reflected tensile cut-off. It is this protracted application of the pressures and the large distances at which they occur, that present the most interesting studies in relation to the collapse of ships' structures. Air blast will only be of importance in the case of shallow-burst bombs, where a considerable portion of the energy of the bubble vents into the atmosphere.

There is an optimum depth of burst in deep water at which the greatest wave height will be produced. This should, conceivably, occur where the depth of detonation is just less than the radius of the bubble to its first maximum; that is, the bubble breaks surface at its first maximum, leaving the greatest cavity. Other causes of waves would be the projectile effect of the emerging column of water, steam, and spray, and the welter of spray and foam—and some solid water—resulting when the column of water falls back into the target area. This was clearly discernible in the films of Test "Baker" at Bikini. Damage and possible swamping could occur to minor vessels, landing craft, etc., but it is thought that major war vessels and merchantmen would suffer little harm from the waves.

If the nuclear reaction proceeds efficiently under water, the same quantity of fission products as with an air-burst bomb will result. If the detonation occurs at an extreme depth and the bubble breaks up before breaking surface, the fission products will be distributed in a column of water between the surface and the point of detonation, with most of them at the zone of break up, and little resulting contamination at the surface. If the detonation is reasonably shallow, however, a vast column of water and steam, in which the fission products are suspended, is projected upwards, and these products are carried down and deposited over the target area as the column descends. It is possible that a small percentage of the fission products, propelled ahead of the rising column, will form a cloud as in an air-burst bomb.

The fission products descending on the target ships and area would be a decided hazard, especially in ships where the water, on evaporating, would leave concentrations behind. The natural salts in the water in the immediate vicinity of the bomb would also be rendered artificially radioactive by neutron bombardment during the detonation. This water goes up in the column with the fission products and falls again over a large area.

These are the problems that face the naval architect, who has to provide some measure of protection for the ships and their crews. Clearly, the degree of protection to be afforded requires careful consideration. To produce a vessel capable of operating after the detonation of a bomb in the air immediately above it would make such demands on weight and space that would react against the ships' offensive qualities, while still allowing the enemy to reduce the height of burst practically to contact conditions, against which, it is suggested, there is no answer at sea.

It is necessary to select some arbitrary distance x and to say "we are going to produce a ship capable of operating after a detonation x yards away," the distance x being a reasonable compromise; for example, if the amount (weight, space and cost) of insulation and shielding needed to preserve life against the effects of heat or radioactivity at so many yards is beginning to climb steeply, then the provision of adequate strength to withstand the air blast at this distance should be thoroughly investigated, to see whether it, too, is acceptable. It is anticipated that this distance would be below the order of normal tactical distances used by ships when operating in company at sea. It is obviously of paramount importance in laying out future fleet anchorages and dockyards.

Clearly, every man above the weather deck cannot wear completely black glasses all day and night in case the enemy should succeed in delivering a bomb without adequate radar warning. Neither can the fact be accepted that all exposed personnel will become blinded (at least temporarily), and reliefs be carried for them. In areas where attack is possible, the number of personnel exposed must always be the very minimum. In the tropics this is a great hardship, but there are palliatives. Navigation and station-keeping radar aids must be developed and their display presented at the bridge (if bridges are still necessary) and lower conning tower, this latter position being instantly ready to take over and con the ship entirely

by radar. All gunnery must become fully automatic, and all mountings turreted.

The above remarks apply equally to protection against heat. Some protection to personnel could be achieved by the use of carefully designed anti-flash clothing and cream, but again, the eyes are vulnerable. Heat would also damage material, scorching and possibly igniting paintwork, wood decks, ropes and canvas, and any exposed inflammable fluids. The remedy is relatively simple.

An air shock wave of the magnitude that must occur from an atomic bomb presents many problems to the designer, engulfing as it does the entire ship in its passage. It must be remembered that the pressures brought to bear on the above-water portions of the ship are magnified above the "free air" pressures, the greatest increase being the "face-on" pressure obtaining on a flat surface at right angles to the direction of motion of the wave. From this, the major consideration would seem to be that a general review of all superstructures is necessary to decide which portions are really essential in these days of radar, and that action should be taken to strengthen the essential portions to withstand the "face on" pressure to which it is desired to work.

A general cleaning up and shaping of structure is necessary to avoid large flat surfaces, re-entrant corners, and hatches and watertight doors in positions where a build-up of pressure is likely. Care must be taken that auxiliaries, machines, etc., are not sited close to structures that are liable to large deflections, and special care will be necessary in aircraft carriers, with their excessive windage area and delicate flight deck machinery. Strengthening of deck beams, and especially corner brackets between the shell plating and decks, will be necessary to combat racking strains.

Blast can penetrate the vitals of a ship through superstructure doors, hatches and ventilation openings and into the machinery spaces through the funnels. This penetration of the ship by blast is one of the more serious aspects. The most likely failures will occur in ventilation trunking to spaces well down in the ship, usually designed only to stand a static water pressure, thus opening up the ship to flooding penetration of fires started outboard, etc., and the entry of radio-active dust. As stated in sections dealing witb light and heat, it seems essential that all guns should be in gunhouses with totally-enclosed directors. Masts and attendant radar antennæ need attention, and, in most cases, strengthening or duplication. The penetration to the boiler-rooms by way of the funnels is one of the most serious results. Funnels will need to be strengthened to prevent them from being blown over the side.

Submarines present their own problems. Most submarines consist of a pressure hull with a superstructure casing and bridge containing the conning tower to which the periscope standards are secured. The pressure hull is ideally suited to withstand the air blast, but the casing is vulnerable, and it has long been the practice to stow inside it quite important pieces of equipment, such as the forward hydroplane operating gear, mufflers, etc. Fittings extending upwards from the bridge, such as periscope brackets, radar, etc., are also vulnerable to air blast.

Underwater shock is clearly of paramount importance in the underwater detonation of the bomb. With the air-burst bomb, there is an underwater shock from the air blast, transmitted through the non-rigid surface interface, but in this case it is not of importance from the damage point of view. On the surface directly beneath the bomb, the full "face-on" pressure is exerted, leading to increased underwater pressures in this region. This phenomenon is later associated with the formation of a wave on the surface of the water. It is against the shock wave from the underwater detonation of a bomb that attention must be directed, since this provides the major structural problems. The structural damage caused by the more orthodox underwater non-contact weapons is reasonably local, with whipping damage elsewhere in special cases. With a detonation of the magnitude of an atomic bomb, however, the whole underwater portion of the ship is subjected to tremendous forces. It is suggested, from an assumption that certain scaling laws apply, that this underwater pressure on the hull becomes practically hydrostatic for a short while. The shock front strikes the vessel and a build-up occurs due to the following positive pressure wave. The duration of this is probably such that the shock wave has passed beneath the keel and the positive pressure pulse diffracted upwards into the water on the lee side, before any appreciable diminution of pressure has occurred on the presented side, resulting in a hydrostatic force all round the ship. Depending on the angle of presentation this will vary with time along the ship, producing varying accelerations and shock waves in the structure.

The shock will be as great in magnitude, and vastly greater in extent, than is encountered from the largest orthodox charges, leading to the usual troubles of cracked castings and the onset of brittle fracture. In addition, there is the sustained hydrostatic push due to the positive pressure phase of long duration, relieved, in the case of vessels of normal draught, by the surface cut-off. Much work remains to be done, both theoretically and practically, in investigating this phenomenon. The practical difficulties in producing the type of shock wave required for model tests present a serious problem.

Waves would be caused by both air-burst and underwater-burst bombs. The waves from an air-burst bomb would be merely the result of the cavity formed, on the surface of the sea by the expanding mass of gases and/or the air blast of the bomb. For heights of detonation greater than, say, 250 ft., the resulting maximum wave height would be small. With an underwater detonation, waves assume greater importance and may cause damage and swamping to minor vessels. The descending column of water would cause minor damage, apart from its effect in generating waves, but it is thought that a vessel which was well closed up would not be endangered. Cargo-hatch covers in merchantmen would probably be stove in or washed away, with the entry of some water.

Radioactivity is one of the most interesting parts of the problem. It is really two separate parts of the same problem: firstly, the intense initial radiation as the bomb detonates, and, secondly, that of dealing with the induced radioactivity and fission products in and on the ships' structure and surrounding water. As would be expected, the air-burst bomb sets mainly the first problem and the underwater detonation the second.

The progress of the chain reaction in the air-burst bomb is accompanied by a violent emission of gamma rays and neutrons, ranging out for hundreds of yards from the point of burst. After the reaction is complete and the flaming mass is slowly rising, it is still emitting gamma rays and some stray neutrons, which will reach the surface of the sea until the cloud rises too high.

ATOMIC BOMBS AT BIKINI.

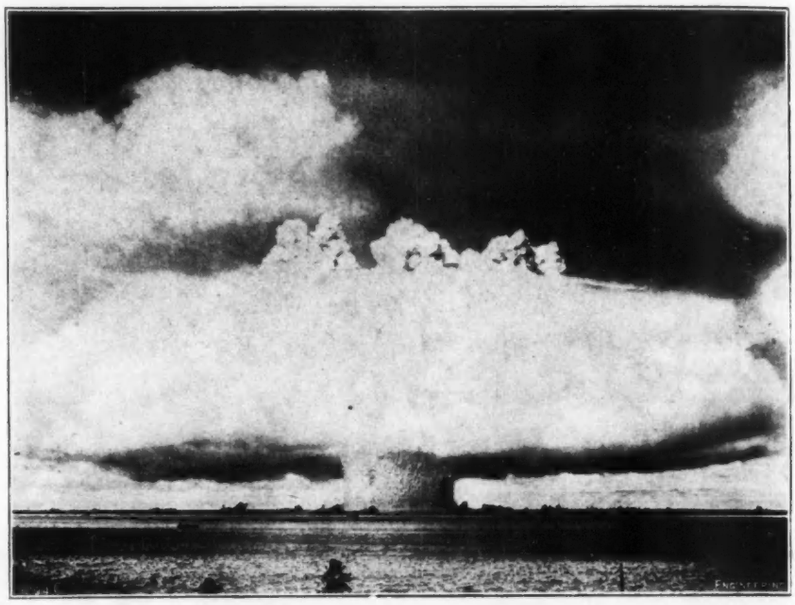


Fig. 3. Later Stage of Underwater Explosion.

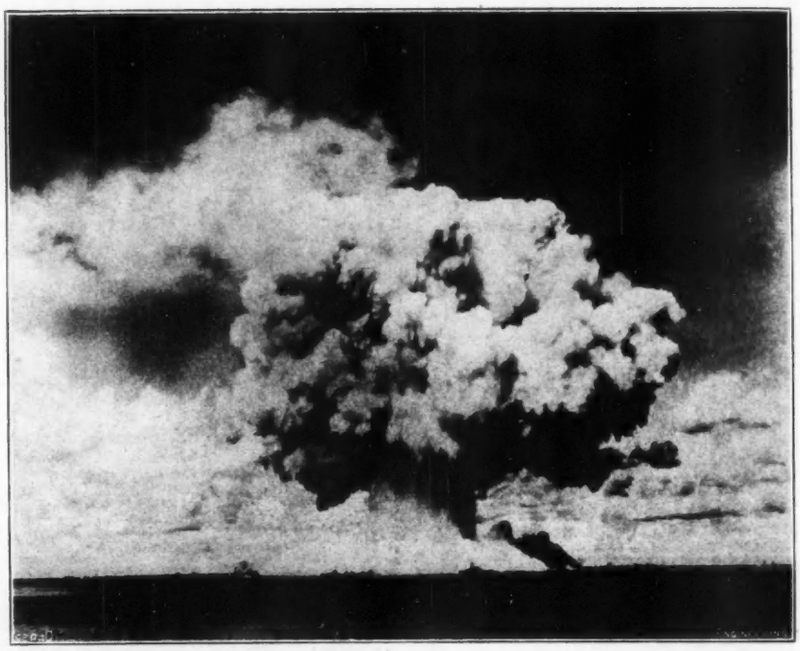


Fig. 4. Column Falling and Forming Area of Spray at Base.

After the mushroom has reached its maximum height and cooled, the radioactive dust starts to fall and drifts away downwind, with resulting contamination.

With the underwater bomb, the initial pulse of radioactivity is probably completely absorbed by the sea water. The radioactive fission products go up in the plume when the bubble breaks surface and fall back into the target area, where they lodge on target vessels or in the water. The salts in the water in the vicinity of the bomb are rendered radioactive by neutron bombardment and behave similarly. The question of protection against radioactivity is again a matter of compromise; with the air-burst bomb, it is necessary to provide against neutrons and gamma rays, while the underwater bomb gives rise to beta particles and gamma rays.

As is well known, the heavier elements are the most effective in absorbing beta particles and gamma rays, whereas some of the lighter elements will absorb neutrons. Both these requirements need to be met if personnel are to survive a nearby air-burst detonation; with the underwater detonation, an effective method of decontamination is the greatest requirement. For protection of hitherto exposed personnel against an air-burst bomb, the same considerations apply that applied to protection from light and heat, save that in this case it is necessary to provide something more substantial than a piece of 5-lb. plating. The provision of adequate shielding by lead or other dense material against gamma rays, and a light medium against neutrons, involves serious complications in local strength, stability, etc., which, to be worth while, will not be acceptable to the designer in producing the types of ships of to-day.

With regard to decontamination after the detonation, and especially after a shallow underwater burst, it will be necessary to introduce a very much cleaner design of superstructure and decks capable of being rapidly washed down. A further problem is presented by the penetration into the living and working spaces of the ship of fission products drawn in by ventilation fans still running after the detonation, or by convection. Even if the fans are stopped, unless there is a valve at the weather deck, radioactive dust will enter and lie in the trunks, being drawn into the ship and distributed over the crew when the fans are restarted. With regard to the underwater burst, all the usual precautions such as anti-shock mounted machinery and equipment, exclusion of iron castings, etc., must be maintained, with additional studies of panel and longitudinal strength problems. Again, it is essential that all openings shall be capable of being closed instantaneously.

It is clear from the few examples given that there is already one type of vessel, the submarine, which goes a very long way to fulfilling most of the requirements. Perhaps the greatest objection to the submarine is that it is comparatively slow. To date, even in such expensive types as H.M. Submarines Severn and Clyde, about 22 knots on the surface and up to 9 knots submerged have been the best service performances achieved. Nuclear energy gives a possible means of improving on these figures, with a notable increase in the power output where most required—submerged.

To utilise atomic energy for industrial purposes, such as ship propulsion, it is necessary that the chain reaction shall be controlled so that the energy which appears as heat and an intense radiation shall be released continuously and at an adjustable rate. There must be no question of the reactor running away, that is, becoming an uncontrolled reaction. It is this "controlled reactor" the atomic pile, which is the probable source of energy in the first industrial applications. It is possible to produce and operate a pile with pure, or nearly pure, fissile material, suitably arranged and operating mainly on fast neutrons; that is, the chain reaction is carried on by the neutrons caused by fission without reduction of their speed (save by collisions) in passing through a surrounding medium. By causing the neutrons to pass through a "moderator," such as graphite or heavy water, they are slowed from their emission velocities of the order of 10^9 cm. per second, and in this state the slow neutrons are much more effective in producing fission, both in U235 and plutonium. Thus, if the fission neutrons can be slowed before they reproduce, the chain reaction can be maintained with either less of the fissile material or with less pure material than in the fast reactor; in fact, natural uranium can be used, avoiding the problems of producing enriched uranium by isotope separation. In addition, the slow neutron reactor has the advantage of simplified control, for some substances, notably cadmium, absorb these slow neutrons, thus providing a ready means of controlling the reaction by adjusting the degree to which the slow neutrons are absorbed by control rods of these substances moved in and out of the reacting pile. Thus whereas the fast reactor depends for its control on the loss of fast neutrons, the slow reactor first slows up the fast fission neutrons in the moderator, and then absorbs some of them in the control rods. A simple automatic control system can be devised.

Since natural uranium consists of about 140 parts of U238 to one of U235, and U238 does not undergo fission, there is considerable neutron absorption by this isotope. This introduces a further stabilising influence, but restricts the choice of a moderator since very little additional loss of neutrons can be accepted. For this reason, water is unacceptable, but heavy water (deuterium) and graphite are very suitable, especially the latter, on grounds of cheapness and the high degree of purity that can be achieved. The multiplication factor (*i.e.*, the number of neutrons directly produced by fission divided by the number of free neutrons present before fission) of a uranium graphite pile is only slightly above unity, and hence control is relatively simple. The disadvantage is that the critical size of the reactor is consequently large, requiring many tons of uranium and of graphite.

Increasing the size of the pile above the critical increases the tempo of fission and the temperature of operation; hence the power output that can be obtained goes up. The best arrangement is to have a lattice structure in which pieces of uranium are disposed regularly through a large block of graphite. The optimum spacing and size of these uranium cores is determined by its nuclear properties; the ideal shape for the completed reactor is spherical, but practical considerations cause some modification to this. The reactors used in the Manhattan Project in the United States were primarily to produce plutonium from uranium, and it was necessary to remove the heat of fission by some form of cooling. Practical difficulties in leading a cooling fluid to the lumps of uranium led to the introduction of the uranium in rod form surrounded by a hollow aluminum pipe through which the coolant flowed, the whole inserted in holes in the graphite. Using this method, the uranium rods could be removed for separation of the plutonium and could also be adjusted to give another form of control.

To avoid contamination of the uranium by fission products and oxidation, it was essential that the cooling fluid (water, in the Hanford piles in the United States) should not contact the uranium. Aluminium was an obvious choice for the sheaths from the point of low neutron absorption, high heat conductivity, and non-corrodibility. This arrangement led to further neutron loss by absorption, with a consequent reduction in multiplication factor, leading to an increased size of pile to reduce the percentage neutron loss by leakage. In the piles used for producing plutonium this cooling problem was an embarrassment, necessitating an ample supply of fresh water and large retention basins to store the hot radioactive water before returning it to the river, in order to provide a delay during which the induced radioactivity could die away.

For a marine application, the first thought is to use the pile as a boiler, producing steam which passes directly to the turbines. This is the most economical way of getting the power, but there are serious disadvantages. The greatest is that, due to the fantastic intensity of radiation in and about the pile, the coolant will emerge with a high level of induced radioactivity. If this is water/steam and is then led directly to the turbines, it will be necessary to provide extensive shielding around the turbines and associated steam piping, with great complications in operating and routine maintenance technique.

To avoid this complication, a heat exchanger can be introduced into the unit. In this layout the coolant, which may be either water/steam or an alternative (liquid bismuth or helium have been suggested), passes out of the heavily shielded reactor room into a less heavily shielded heat exchanger or boiler-room, where it transfers its heat to the boiler feed-water and then passes back, possibly through a series of smaller exchangers and a sea water cooler, and a retention tank, to the reactor. The steam generated in the heat exchanger would pass to the turbines. A disadvantage with a water/steam cooling system is that the system would be required to work at a considerable pressure in order to achieve a reasonable thermal efficiency, and hence the aluminium sheaths would have to be thicker, and would absorb more neutrons, than in circuits using the alternative coolants suggested above. This would lead to an increase in the size of the pile for a given power output.

All control operations must be remotely operated. The neutron density at various points in the pile is recorded and automatically causes the control rods to be pushed farther in or withdrawn. In an emergency the uranium rods could also be rapidly withdrawn. Provision must be made to withdraw and replace the uranium rods periodically, for it is probable that in time the power level of a reactor will fall off due to choking by fission products formed in place of the U235. Similarly, some of the U238 will be transmuted to plutonium and it may be desired to separate this valuable product at the same time. Alternatively, it may be found possible, by gradually changing the working characteristics of the reactor, to burn the plutonium formed in the rods without removing them from the pile.

A possible solution to the coolant problem for installations where it is not essential to keep the ship closed up all the while might be to use air, the air being drawn into the reactor from the weather deck, circulated either to a heat exchanger or actually used as the driving fluid itself in a turbine and exhausted at high velocity into the air above the ship. This would avoid the necessity for retention tanks, and the air, due to its single rapid passage through the pile, might not become too radioactive, allowing some reduction to be made in shielding in the machinery spaces outside the reactor room. Objections to the scheme of using air as the coolant leap readily to mind, such as the ducting necessary to carry the enormous volumes of air required and the difficulty of using this system in harbour because of the exhausted radioactive air.

Despite the manifold difficulties in introducing the nuclear reactor for industrial power production, the fact remains that the reactors are extraordinarily compact and are able to run for long periods without refuelling. The power available from a given plant is limited only by the rate at which the heat can be extracted, subject to the operating temperature being below the melting point of the materials making up the pile. Uranium melts at about 1,150 deg. C. The greatest disadvantage and one that will cause the naval architect the most trouble, is the fact that the nuclear reactor is a source of intense radiations, both gamma rays and neutrons. For this reason, very extensive shielding must be provided all round the pile and the emerging cooling pipes, to protect personnel. For a plant giving some 150,000 shaft horse-power something like 800 tons of steel and concrete shielding will be needed around the reactor room itself, with additional shielding around associated heat-exchanger rooms, and perhaps the turbines.

All control operations on the reactors, heat exchangers and (possibly) turbines will have to be remotely controlled from a heavily-shielded control position, and no maintenance work on these systems will be possible at sea. This brings up another point—the effective life of a reactor, and maintenance difficulties. Every part of a pile is subject to an intense neutron bombardment and becomes radioactive. This intense bombardment and irradiation with gamma rays has an effect on the structural properties of materials in the pile, destroying the molecular bond of many molecules, especially in compounds. Elements and ionic compounds are best, since they tend to resume their original state when the radiations cease. Complete breakdown is possible in structural materials in and around piles working at high power outputs and temperatures such as those envisaged, and this may possibly limit the size and power output that we can obtain from an atomic reactor.

With regard to maintenance, consider the problem that arises in the case of a fault developing in the reactor or heat-exchanger rooms, and to a lesser degree in the turbine room. Depending on the seriousness of the fault (and with this system the few defects that can develop are serious) the pile would have to be reduced in power, or shut down completely, and the ship sailed or towed to harbour. Due to the intense radiations from the fission products and structure of the pile, no one would be able to open up or enter these spaces for a considerable period, possibly months, thereby placing the vessel out of commission for this period. Without doubt, an outstanding measure of reliability with reactors will finally be achieved, with mechanical methods of replacing uranium and control rods and suspect cooling conduits while still at sea, but the fact remains that to survey the reactor and its compartment, and the heat exchangers, retention tanks, etc., the induced radioactivity in the structure must be allowed to die away naturally, with consequent delay.

The particular advantage of this system of propulsion, operating on a closed coolant and feed-water cycle through a heat exchanger, is as applied to underwater craft, where the development of the true and fast submersible becomes possible. Here there are no problems of combustion and fuels, and oxygen to support this combustion and even the nuclear problem of shielding can be reduced by intelligent design.

INSTITUTE OF BRITISH FOUNDRYMEN AWARDS.—The Council of the Institute of British Foundrymen have awarded the E. J. Fox Gold Medal for 1948 to Mr. J. G. Pearce, M.Sc., in recognition of his services to the foundry industry during the many years he has been Director of the British Cast Iron Research Association. The Council, in addition, have awarded the 1948 Oliver Stubbs Gold Medal to Mr. L. W. Bolton, A.M.I.Mech.E., for his outstanding services to the Institute and to the Industry, and the 1948 Meritorious Services Medal to Mr. C. Lashly, M.C., for his work as honorary secretary of the Newcastle branch of the Institute for many years. The presentations will be made at 9.30 a.m. on June 9, during the annual meeting of the Institute to be held at the Café Royal, Regent-street, London, W.1.

NOTES ON NEW BOOKS.

Writing the Technical Report. By PROFESSOR J. RALEIGH NELSON. McGraw-Hill Book Company, Incorporated, 330, West 42nd-street, New York 18, U.S.A. [Price 3 dols.]; and McGraw-Hill Publishing Company, Limited, Aldwych House, Aldwych, London, W.C.2. [Price 15*s.*]

IN this "new second edition" of a book first published in 1940, the author, who is professor of English in the College of Engineering, University of Michigan, has revised his analyses of methods and strengthened his links between theory and practice. The purpose of the book is to show technical people how to convey information in writing, and the report is distinguished from other expository writing by the fact that it is prepared for a particular reader who wants specific information or advice. The specific use determines for the report its plan, scale, method of treatment and amount of interpretative comment. Professor Nelson believes that the first thing, for a technical man seeking to express what he knows thoroughly, is the correct structure for his report; grammatical construction is not forgotten, but is made subordinate to object and plan. Because of this, the book rises above the level of irritable quibbling on which so many writings about writing wallow, and is constructive, practical and encouraging. The main elements of a report are stated to be the introduction—an outline of subject, purpose and plan; the subject-matter; and the conclusion—a bringing together of the essential points, with appropriate opinion or summary of results. In this book, much space is helpfully given to an examination of the paragraph, with a conception of it that may be new to some and refreshing to many: "an adjustment of the amount of material to be delivered during any one moment of concentrated attention, to the capacity of the reader for such attention." Examples of poor and revised work are separated from the main argument, which is so much the freer from negative advice. By regarding the report as a collection of material to be valued, sorted, arranged, tested and re-arranged—rather than a piece of prose to be coaxed out of the writer's head through an uninspired pen—it becomes possible to relegate grammar, as such, to ten pages near the back of the book; even then, the author merely deals with "common difficulties with the English sentence." With over 380 pages of fairly close type, the book is too long and too business-like for the reader who wants easy recipes for dashing off trenchant letters and memoranda; nor will it help the would-be facile article-writer who wishes to avoid thinking. Students will find Professor Nelson's to be the hard way, but with him they are likely to arrive; battered, perhaps, but freed to say what they mean clearly, with form, and not without grace.

A Study of Mechanically-Produced Foam for Combating Petrol Fires. By DR. N. O. CLARK. D.S.I.R. Chemistry Research Special Report No. 6. H.M. Stationery Office, Kingsway, London, W.C.2. [Price 2*s.* 6*d.* net.]

THIS report is a technical document of some 110 pages which describes some of the work carried out at the National Physical Laboratory during the war years in order to find readily available foam-producing materials suitable for the smothering and extinction of petrol fires. On the outbreak of war, in 1939, most of the suitable substances used in this country were costly and depended on imported materials; moreover, the factors which govern the formation of a suitable foam were imperfectly understood. Consequently, the N.P.L. were asked to investigate the problem, and to find suitable materials. In this they were largely successful, and a foaming agent of high performance was developed from indigenous materials. This was manufactured in Great Britain and Ireland and used by the Royal Air Force. The report is broadly divided into four sections. With the help of tables, graphs and illustrations, it describes in considerable detail the theoretical and practical work carried out during the investigation and discusses the results obtained. In the first section, a brief review is given of earlier work relating to foam formation, and the second section describes the experimental techniques developed in order to measure the properties of foam, such as its viscosity and its stability at normal and elevated temperatures. The third and fourth sections discuss the investigations made on various foam-producing materials, and on the stability and behaviour of foams under various conditions. It is concluded that the most suitable compounds for use in fighting petrol fires are those "which in solution exhibit strong superficial viscosity," and, that the performance of a foam can be estimated roughly from laboratory measurements of its properties. The report, which is a record of work carried out by the Chemical Section of the N.P.L., does not describe the steps taken to make full use of the results obtained.

"ENGINEERING" ILLUSTRATED PATENT RECORD.

ABSTRACTS OF SPECIFICATIONS RECENTLY PUBLISHED UNDER THE ACTS OF 1907 TO 1939.

The number of views given in the Specification Drawings is stated in each case; where none is mentioned, the Specification is not illustrated.

Where inventions are communicated from abroad, the Names, etc., of the Communications are given in italics.

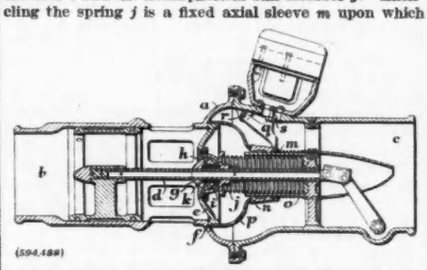
Copies of Specifications may be obtained at the Patent Office Sales Branch, 25, Southampton Buildings, Chancery-lane, London, W.C.2, price 1*s. each.*

The date of the advertisement of the acceptance of a Complete Specification is given after the abstract in each case, unless the Patent has been sealed, when the word "Sealed" is appended.

Any person may, at any time within two months from the date of the advertisement of the acceptance of a Complete Specification, give notice at the Patent Office of opposition to the grant of a Patent on any of the grounds mentioned in the Acts.

AERONAUTICS.

594,468. Measurement of Fluid Flow. Westland Aircraft, Limited, of Yeovil, Somerset, and W. M. Widgery, of Yeovil, Somerset. (1 *Fig.*) May 15, 1945.—This invention relates to means for measuring the flow of air into or out of a pressurised cabin of an aircraft. A casing *a* furnished with an inlet opening *b* is connected to a centrifugal air blower (not shown) and is provided with an outlet *c* connected to the cabin (not shown). This casing embodies a central axial fixed guide *d*, upon which is mounted a non-return valve *e* engaging a seating *f* on the casing. The mounting of the valve incorporates a hemispherical ball member *g* which slides upon the guide and engages a ball socket surface A on the valve. The mounting also incorporates a spring cup member *i*, thrust axially by a helical compression spring *j*, a further compression spring *k* being provided between the cup member *i* and the hemispherical ball member *g*. Encircling the spring *j* is a fixed axial sleeve *m* upon which



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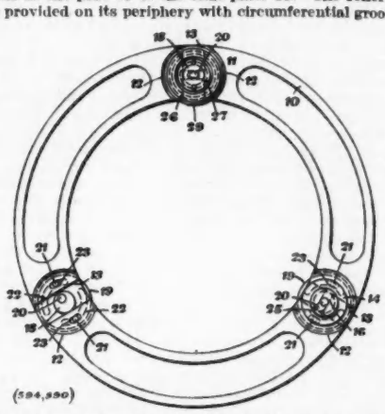
slides a conical sleeve *n* which is urged axially by a further spring *o* encircling the fixed sleeve; the conical sleeve abuts an annular facing member *p* secured to the non-return valve. Bearing upon the conical surface is one end of a lever *q* pivoted at its other end to the casing at *r*. At a point intermediate between its ends the lever bears against a plunger *s* operating through the wall of the casing and communicating motion to a remote flow-recording apparatus, to which the motion is conveyed by electromagnetic means. In operation, on the opening of the non-return valve *e* to permit flow of air from the blower to the cabin through the casing, axial movement is imparted to the conical member *n*, thereby rocking the pivoted lever *q* and, in turn, thrusting outwards the motion transmitting plunger *s*. The extent of movement of the plunger is a measure of the degree of opening of the non-return valve and thus the flow of air past the valve is indicated on the flow-recording apparatus. The provision of the ball mounting for the non-return valve at *g* allows for variation in the alignment of the valve with its seating. (*Sealed.*)

MACHINE TOOLS AND MACHINE-SHOP EQUIPMENT.

594,890. Screw-Thread Gauge. Rotol, Limited, of Gloucester, B. Teague, of Churchdown, Gloucester, and V. G. Parry, of Gloucester. (6 *Figs.*) December 21, 1944.—The invention is a gauge for checking the accuracy of screw threads. A ring 10, which is mainly of H-section, is provided with three solid portions 11 to receive the gauging rollers. These portions 11 are bored on one side to provide a cavity 12, this cavity opening to the inner and outer peripheries of the ring 10. At the bottom of the cavity there is a groove 13 which is radial to the ring 10 and receives a slide plate 14 of circular form with a projecting part to engage and slide in the slot 13. This projection is formed with a transverse slot 16. A hole through the ring 10 opens into the groove 13, this hole receiving the spindle 18 of a cam-plate 19 which is mounted on the other side of the ring. On the end of the spindle 18 there is an eccentric pin 20 which engages in the slot 16, so that when the cam-plate is rotated, the eccentric pin moves the slide-plate 14 radially along the slot 13. The cam-plate 19 is locked in position by screws 21 passing through arcuate slots 22 in the cam-plate and through shorter slots 23 in the ring, and being screwed into the slide-plate 14. The slots 23 in the ring permit the radial movement of the guide-plate and screws 21. The slide-plate 14 carries an extension 25 which forms a journal bearing for a roller 26, this roller being retained in place by a retaining-plate 27 having a screw-threaded extension which is screwed into a suitable hole in the part 25 of the slide-plate 14. The roller 26 is provided on its periphery with circumferential grooves



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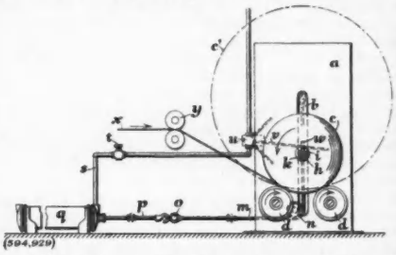
29 which are formed accurately to the contour of the thread which is to be gauged. The spacing of the rollers 26 in the frame 10 is such that the rollers overhang the inner surface of the gauge so that they can be engaged with the screw-thread to be tested by applying the frame 10 to it like a nut. In the case of testing an internal thread, the rollers 26 are arranged to overhang the external periphery of the frame. Three grooved rollers are provided, but to show the construction more clearly, the grooved roller is omitted on the bottom right-hand side, and the roller and its side plate are omitted on the bottom left-hand side. (*Sealed.*)

TEXTILE MACHINERY.

594,929. Formation of Rolls of Sliver from Long Staple Fibres. James Mackie and Sons, Limited, and J. P. Mackie, both of Belfast, Northern Ireland. (2 *Figs.*) July 4, 1945.—The object of the invention is the formation of large-diameter rolls of sliver from jute, sisal and similar long staple fibres. Compressed air is used to exert pressure on the roll, instead of weights or hydraulic pressure. In the front elevation shown, one of the side plates is omitted to show the mechanism behind it. Two side plates *a* are provided, mounted on a suitable base, and a sliver roll *c* is wound on a spindle between them. The plates are slotted vertically at *b* for the passage of the spindle around which the winding is effected. The sliver *x* is delivered between rollers *y* to the sliver roll *c* which is rotated by resting upon a pair of rollers *d* geared together by toothed wheels and an intermediate pinion. The sliver rolls are coiled around hollow wooden centres *i*, through which a spindle *h* can be passed, the ends of this spindle projecting through the slots at *b* which guide them. In order to apply downward pressure to the spindle *h* and the sliver roll *c*, shackles *k* are provided having ball-bearing centres in which the



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spindle *h* fits, these shackles being slipped on to the ends of the spindle *h* and loaded downwards by wire ropes *m* passing around guide pulleys *n* to a yoke *o*. This yoke is connected to a piston rod *p* projecting from a piston in an air-pressure cylinder *q* mounted in a fixed position at the rear of the coiling machine. Air under pressure is supplied to the cylinder *q* from a pipe *s* through a cock *t*, and can be released through an escape valve (not shown). The roll *c* increases in diameter and weight during the winding until it attains the size indicated in chain-dotted lines at c^1, and if the air pressure is constant the pressure at which the sliver is wound on the coil is continuously increasing. To avoid this a pressure-controlling valve *u* is provided in the air pipe, with a rod *v* projecting from it and passing between projections *w* on the guide through which the spindle *h* passes. As the spindle rises while the roll *c* increases in size, the rod *v* turns and constantly reduces the air pressure in the cylinder *q*. (*Sealed.*)